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ELECTRICAL SECTION.

Stated Meeting, Tuesday, Dec. 13, 1898.

THE KITE AS AN INSTRUMENT OF METEOROLOGICAL RESEARCH.

BY PROF. CHAS. F. MARVIN,
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There is, I think, a peculiar coincidence in addressing the members of the Franklin Institute this evening upon the subject of kites, inasmuch as our beloved Franklin himself was the first to demonstrate in this very city the usefulness of kites in resolving the mysteries of the upper air.

The century and a half that has now almost passed since the famous Philadelphia experiments were made has not added all we could desire to our knowledge of kites, but I trust my remarks may, in a very small measure, commemorate the same name so grandly perpetuated in the splendid work of the Franklin Institute.

I have just said that Franklin was the first to demonstrate the usefulness of kites, but this is not exactly the

case, because we now know that two or three years prior to Franklin's sublime analysis of the thunderbolt, Dr. Alexander Wilson, of Scotland, flew kites with thermometers attached, in order to ascertain the temperature of the upper air. However, these experiments of Wilson's were not described and published until many years afterwards, and his work is justly overshadowed, both by the remarkable revelation in Franklin's discovery, and by the energy he displayed in bringing it to the attention of the scientists of his time. The electrical kite immediately became the rage, so to speak, all over Europe, but attention was directed very largely to the electrical effects, and very little to the kite itself. A notable exception of this indifference respecting the kite is found in a remarkable mathematical paper by Euler, eldest son of the famous mathematician of that name. Stimulated by the scientific use of the kite made by Franklin and many others, Euler worked out an exhaustive and elaborate mathematical analysis of the behavior of the kite.

This interesting paper was published in the "Memoirs of the Berlin Academy for 1756," but since then it seems to have been very nearly lost sight of and forgotten, and is now scarcely known. Its present interest, moreover, is chiefly historical, from the fact that the whole mathematical structure rests upon certain assumed conditions of flight that differ so widely from actual conditions that the final deductions are of little practical value. For example, it is assumed that the pressure of the wind upon the kite varies as the square of the sine of the angle of incidence. Also, that the action line of the resultant of this pressure passes always through the center of figure of the surface. Such assumptions are now known to be untenable. Euler assumed, furthermore, that the kite and the string were, together, a rigid structure; consequently, when the kite rises and falls the motion would be simply the turning of this rigid body about the fixed end of the string at the ground as a pivot. In taking the weight of the string into account, Euler neglects its curvature, but this is done in a manner that virtually affirms that the string is a rigid, heavy line. In other words, the resulting equations are such as would apply if

the kite were flown with a slender, rigid rod instead of a flexible string. Final deductions, resting upon such assumptions, have little practical significance.

Since Franklin's time a careful search shows that kites have been repeatedly recognized and, from time to time, employed as a useful piece of aërial apparatus. The first notable meteorological observations made with kites are doubtless those carried out by Archibald, in England, from 1883 to 1885. The object of these experiments was to ascertain the rate of increase of wind velocity as we pass upward from the earth's surface. This was determined on many different occasions, and, with much care, by means of anemometers carried aloft by kites.

Coming to still more recent times, it may be said that two causes have contributed very largely to greatly increase the use of the kite in aërial research. The first, and probably the more important of these, is the invention, within the past ten years or so, of greatly improved types of kites. The second cause is found in the development and manufacture of very light forms of automatic meteorological instruments. These latter enable us to measure and record at the kite the several meteorological conditions of air in which it floats, a thing which could scarcely be done, even in Archibald's time, that is, only ten to fifteen years ago.

Mr. Wm. Eddy, of Bayonne, N. J., deserves great credit for his work in perfecting a form of tailless kite. This is now generally known throughout the United States as the "Eddy" kite, and is doubtless familiar to many of my hearers.

Almost a revolution has been effected in kite-flying by the invention of the so-called cellular or box kites. This invention dates back to 1893, and is due to Mr. Lawrence Hargrave, of New South Wales, Australia. A description of these kites was read at the International Conference on Aërial Navigation, held at Chicago, at the World's Fair. Fully two years elapsed, however, before this remarkable innovation in kite construction received the attention in this country that it deserved. In the meantime Hargrave himself was busy at work perfecting and building large

size models, and actually hoisted himself into the air to a height of 40 feet with a string of his kites. The description of these remarkable experiments, published in the *American Engineer* for April, 1895, seems to have drawn the attention of kite-fliers in the United States to this type, which, I think I may safely say, is now superseding all other forms for meteorological work.

The exploration of the upper air is a subject upon which the Weather Bureau has expended a great deal of effort ever since its organization. Long series of observations have been maintained on lofty mountain summits; large numbers of balloon ascensions have been made under its auspices, and, finally, meteorological kites have been called into requisition, all with the same object in view, namely, to find out more exactly what is going on in the upper air. Observations upon mountain tops give one kind of information. Another class of data is obtained from balloons as they ascend and descend through the air currents in which they float. Finally, kites enable us to obtain still a third class of very valuable data. From my experience with the subject, I am satisfied that kites can, and I believe they will, be perfected very much beyond their present state, and in that case they will, no doubt, in the future, find a permanent place among the instrumental equipment of meteorological observatories.

In the fall of 1895, Prof. Willis L. Moore, the Chief of the Weather Bureau, decided to undertake investigations for the purpose of ascertaining to what extent the kite equipped with self-recording instruments is available in making *daily* soundings of the atmosphere to a height of a mile or more. It was then well known at the Bureau that the mere addition to the kites of a small load in the shape of recording instruments involved no new difficulty in securing an ascension. This had been repeatedly demonstrated in the preceding 150 years. The real problem was to produce thoroughly trustworthy kites that would, themselves, reach great elevations, and do this *daily*, if possible, and without frequent mishap and loss. It has been my pleasure to have charge of this work during the past three years.

At first the work was purely experimental, during which stage many important improvements were effected in the design and construction of kites; a sound mechanical basis was formulated to explain the action of the forces due to the wind and string, and methods were established by which to measure and express the efficiency of kites. This period was followed by one devoted to inventing and perfecting appliances embodying the results of previous experiments and which were adapted to be issued to stations and used in making daily ascensions.

Finally, coming down to the present year, sixteen of the regular stations of the Weather Bureau, in addition to one at Washington, were equipped with complete kite-flying outfits, each in charge of a special observer who received at Washington a preliminary training in the art and practice of flying kites.

This undertaking on the part of the Weather Bureau is a notable step forward in meteorological research. The very limited funds available, however, has confined the work, thus far, to a mere preliminary survey, and during the present month it has been necessary to suspend operations at all but two or three of our aërial stations. Nevertheless, enough has been brought out in what has been done to demonstrate the cheapness and availability of this means of aërial exploration, and plans are now maturing for marked improvements in both the kites and the meteorological instruments.

The United States, represented by its official corps of Weather Bureau kite observers, under Professor Moore, and ably supported by the splendid independent achievements in kite building and flying of such experts as Ferguson, Clayton, Eddy, Wise, Lamson, Woglom and many others, has undoubtedly taken the lead in perfecting kites and employing them in aërial researches, but a great many workers on the problem are now in the field all over the world, and we may reasonably expect very great improvements in kite-flying in the near future.

I have attempted to give in the foregoing a very brief historical sketch of the use of the kite in aërial research,

but I realize how imperfect it is, and that it has been impossible to include many essential points without extending this portion of my remarks to too great length.

THE WEATHER BUREAU APPARATUS.

In designing the apparatus employed at the Weather Bureau stations it was necessary to adopt such forms and types as could be used everywhere alike and by persons having no previous experience either in kite-flying or even in general meteorological work. Fifteen of the seventeen aërial observers had never taken part in flying kites for scientific work at the time they reported at Washington for two weeks' instruction in the work, before taking charge of their several stations. Only four of the men had had previous experience in conducting the regular meteorological work of our stations. The new men were drawn from the lists of eligibles who had passed the civil service examinations for Weather Bureau observers.

Taking this inexperience into consideration, and the comparatively untried and unperfected nature of the whole mechanical apparatus employed, the very satisfactory results of the first six months' work testify both to the general correctness of judgment displayed in the choice of the appliances and to the entire practicability of using kites in such investigations.

Kites were broken from time to time, and from 10 to 20 per cent. of the entire supply of steel wire employed in flying the kites was lost or rendered unserviceable by entanglement, etc., but not a single one of the registering instruments sent up with the kites was lost or even seriously injured. This gratifying result is attributed very largely to the practice uniformly adopted in the Weather Bureau work of suspending the meteorograph within the framework of the kite. Even if the latter breaks away, its fall through the air is slow, and the nature of the structure is such as to completely protect the instrument from any severe shock or injury when the kite strikes the earth or other objects in its descent. Those who advocate flying several small kites in tandem, as compared to one large kite, are compelled to sus-

pend the meteorograph at some point on the main line below the kites, where their combined action is effective in supporting it. The instrument in such a position is exposed to much greater danger of loss and injury than within a kite large enough to fly efficiently in spite of the increased weight. The superior efficiency of one large kite over several small ones was fully demonstrated in our early experiments,* and, in proportion to the length of line used, the supporting surface spread to the wind, the weight of instru-

FIG. 1.—Weather Bureau kite and meteorograph.

ment carried and the tension on the line, the elevations reached by the standard kites of the Weather Bureau show them to be much more efficient than any whose records of efficiency have, thus far, come to our notice.

Standard Weather Bureau Kite.—I am fortunate in being able to exhibit this evening this large kite (*Fig. 1*) before you, which was built and kindly placed here for my use by

* Kite experiments at the Weather Bureau. *Monthly Weather Review*, Vol. XXIV, p. 253.

Mr. Charles Day, of Germantown, Pa. It represents, in all essential respects, the medium-size Weather Bureau kite; the only differences are in the structural details. The supporting surface of this kite measures 68 square feet. A smaller kite, with about 45 square feet of supporting surface, and a slightly larger one than this, with 74 square feet of surface, have also been employed. In order to permit of easy transportation to stations, the kite readily admits of being collapsed to the shape shown in *Fig. 2*. The general plan of

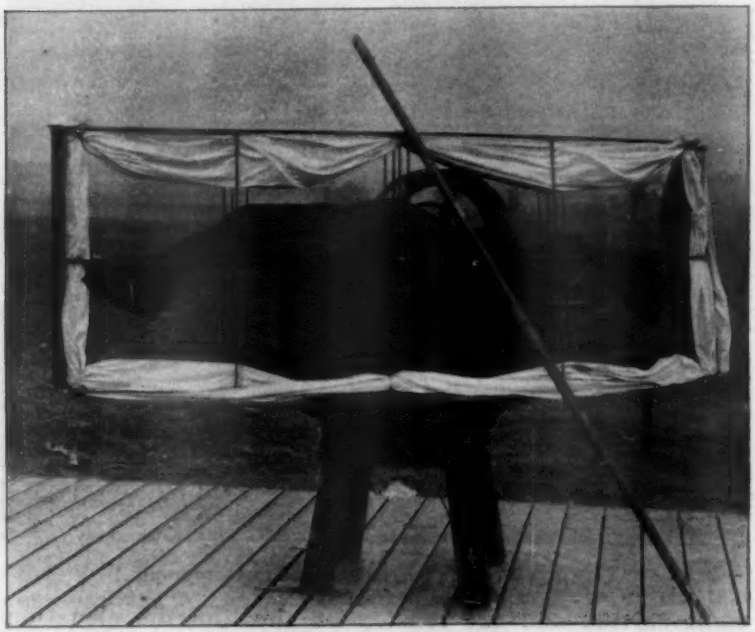


FIG. 2.—Kite collapsed.

construction is gathered from this figure. Four rectangular frames, 78 inches by 32 inches, are formed of straight-grained spruce strips, $\frac{3}{8}$ inch by $\frac{1}{4}$ inch, cross-section, rounded edges. Each frame is braced by transverse struts and further made rigid by four exactly equal ties of tempered steel wire. These are stretched slightly taut from each corner of the frame to the top and bottom ends of the middle brace. All points of junction of the sticks of the frame are formed by

the aid of light sheet-tin angle pieces, punched out under dies in a form to fit the wood exactly, and at the same time give the maximum stiffness to the thin sheet metal. The tins and the wood are all lashed firmly together by No. 16 gilling thread, thoroughly coated with soft shoemakers' wax. The angle tins are formed with a view to providing a secure point of attachment for the ties, the wire of which is twisted up at each end to form an eye large enough to admit a wire nail about $\frac{1}{16}$ of an inch in diameter. The steel wire has a tensile strength exceeding 200 pounds, and the tins, as shown by tests, afford an unyielding point of attachment of equal strength. Similar tie wires contributing rigidity to the kite in the longitudinal sense, though slack, are not detached when the kite is collapsed, but come taut when the longitudinal spines are put in place. This is accomplished in a few minutes by the aid of small machine screw bolts, which pass through the longitudinal spines and clamp them to parts of the angle tins employed in joining the members of the rectangular frames. The cross-section of the corner spines is $\frac{1}{4}$ inch by $\frac{3}{8}$ inch; that of the central top and bottom spines is $\frac{1}{2}$ inch by $\frac{3}{8}$ inch. The cloth bands are 24 inches wide, and the distance between cells has varied from 24 to 30 inches. Excellent results have been obtained with a distance of 28 inches between cells. The cloth is prepared in strips of sufficient length; the edges and ends are hemmed with a cord inserted. The strip is then placed around the frame of the kite and the ends sewn together; the edges all around being also sewn to the sticks of the rectangular frames. The white cloth in the front cell is Lonsdale cambric, which is of very close weave and is stronger than the black percaline chosen for the rear cell on account of its color, in order to increase the visibility of the kite.

According to the theory of the kite, fully confirmed by practice, the principal function of the rear cell is simply to preserve equilibrium between the forces due to the wind, the string and gravity, and, except when the wind is very light, the pressure per unit area on the forward cell is many times that upon the rear cell. Under these circumstances, the correct procedure in order to secure greater lifting

power per unit weight for the whole kite is to increase relatively the proportion of surface in the forward cell, which explains why the front cell, in the Weather Bureau kite, is provided with three supporting surfaces while the rear cell has but two.

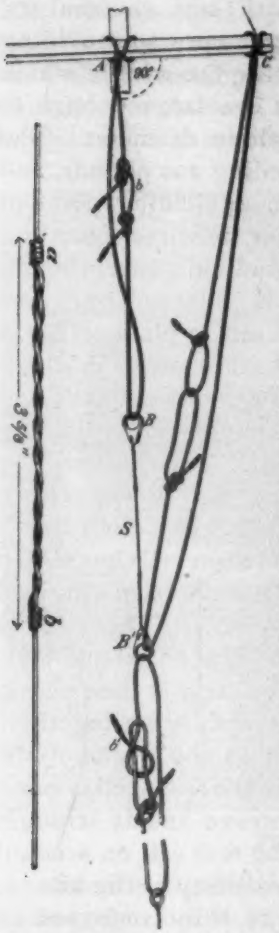


FIG. 3.—Bridle and splice.

The Bridle.—Whatever connection in the nature of a string or cord is employed to join the main line to the kite frame may be designated by the term bridle, the exact arrangement of which varies greatly in different kites. Mechanical considerations show that certain advantages arise when the kite is so bridled that the point of attachment of the main line to the frame is well forward (the forward end of a kite is the end the wind first encounters as it flows over the structure in normal flight). Under these circumstances the kite tends, in a greater degree than otherwise, to "spill the wind" from the sails, under strong gusts, and, with this end in view, the Weather Bureau kites are bridled at a single point, namely, the middle point of the foremost lower edge of the front cell. The presence of three, instead of two, supporting planes in the front cell improves the action of the kite when bridled in this manner. Notwithstanding the advantages realized in this bridle, the pull of the kite in the very strongest winds will increase to a dangerous point, and another device, called a safety line, has been employed, in order to prevent the breaking of the main line or the kite when the strain becomes dangerous. The standard kite and line are safe, as a rule, when under a

strain of from 85 to 100 pounds, and generally withstand considerably greater strains. However, the safety line is chosen from fine, tempered steel wire having a tensile strength of about 85 pounds. A short piece of this is inserted between the main line and the kite, as shown at *S* in *Fig. 3*, and carries all the strain, which, on exceeding 85 pounds, will necessarily break the safety line; whereupon another connecting line, previously idle and a little slack, immediately comes up taut, and the kite thereafter flies from a new point of attachment, *C*, several inches in advance of the normal point; all of which has the effect of reducing the strain on the kite under the same wind force.

It is often suggested that in place of the safety line, *S*, an elastic cord or spring be used, which, stretching with increased strain, transfers the equivalent point of attachment from *A* towards *C*. If the mechanics of this arrangement be analyzed, it will be readily seen that to be effective the point *C* must be carried very much further forward than otherwise required. It is claimed by some who have advocated the use of this device that it limits the strain on the line in gales of wind. It is easy to demonstrate the fallacy of this simply by the parallelogram of forces; in fact, it is obvious that the elastic connector will not stretch more and more as required, except as it is subjected to greater and greater strains; but this is not the only difficulty, for, as the elastic stretches a little, a part of the strain is carried to the point *C*, and the total strain that must be carried by the line and kite increases at a greater rate than the part of it which tends to stretch the elastic connection, thus nullifying the advantage claimed. On the other hand, the safety line, in spite of certain obvious defects and objections, possesses highly valuable features.

The Line and Reel.—Steel music wire is the best material for kite lines, on account of its great strength in proportion to weight, and especially on account of its slender cross-section; the pressure of the wind upon the line being a very important detrimental factor in limiting the elevation of ascensions. The wire used in the Weather Bureau work

has a tensile strength of over 200 pounds, and measures ·028 of an inch in diameter. It can be drawn in lengths of 7,000 feet or thereabouts, if necessary, so that but few splices are required. Where splices are needed, these are made by twisting the wires together in the manner shown in *Fig. 3*, the joint being thoroughly soft-soldered at a low heat.

FIG. 4.—Hand reel.

The station at Washington is equipped with an automatic steam windlass, but a very conveniently mounted hand reel, as shown in *Fig. 4*, was issued to stations. The iron drum is cast in one piece, the metal in the rim being about $\frac{5}{8}$ of an inch thick under the wire. The rim can safely resist a crushing force exceeding 200,000 pounds.

This enormous strength, as is well known, is necessary to withstand the cumulative effect of winding on a great many turns of wire under strong tension. A single turn of wire around the drum, under a uniform tension of 50 pounds, for example, subjects every transverse section of the rim to a compressive force of 50 pounds. The next turn at the same tension adds 50 pounds to the preceding pressure, and so on. Two thousand turns at this rate will, therefore, produce a crushing pressure of 500 tons. In actual practice, the crushing pressure is not quite so great as this, because the wire yields a little as the pressure increases, and this lessens the tension of some of the turns of wire already in place on the drum. The crowding of the wire laterally tends also to burst off the side flanges, and, to obviate this, it is best to wind the wire on in a regular crisscross fashion, which both lessens the lateral crowding and also prevents the wire passing onto the reel from squeezing through and entangling with what is already wound on.

The circumference of the drum is about 5 feet, and suitable dials, moved by a worm on the axis of the drum, indicate the number of turns of wire paid out. The length of wire is deduced from the dial reading, due allowance being made for the change in the circumference as more and more wire is wound on or off.

The unwinding of the drum is controlled with great ease by a strap-iron friction brake working on a flange of the drum and operated by the lever seen at the right in the picture. The reel box turns in azimuth on the table beneath, and can thus be adjusted to the kite in any direction of flight.

The tension on the wire is shown by an index and scale attached to one of the crank handles. A hook on the reel box can be readily engaged in a spring on the end of this crank handle, and serves the double purpose of locking the reel against further unwinding, and the position of the index shows the strain on the wire at all times. The crank handles are made of wood, thoroughly shellacked, in order to electrically insulate the operator from the metal reel and wire, which are generally electrified during ascen-

sions. The metal parts are, however, all connected to "earth" by means of a wire and iron rod driven into the ground a few feet. A small switch in this circuit enables the operator to judge of the extent and nature of the electrification by means of the sparks which jump over a gap in the circuit.

The slender, bent, aluminum radial arms, together with the graduated arc of a circle, seen in the picture, constitute an arrangement for measuring the inclination of the wire line to the horizontal. The arc is supported on two small

FIG. 5.—Nephoscope (Marvin).

wheels which run in a groove on the shaft, the correct position of the arc being assured by a weighted rod pendent below the center of support. The several parts of the reel may be detached with complete facility. The cranks and radius rod, when not in use, are stowed inside the box, which is then covered and locked. The wire is sufficiently protected from the weather by keeping it thoroughly coated with vaseline applied by a brush from time to time to the wire on the reel.

Ordinary Conditions of Flight.—In a favorable wind of from 15 to 20 miles per hour at the surface, the kite will fre-

quently fly at an angular elevation of a little over 50° with about 5,000 feet of wire out. In the highest ascensions yet reached with a single kite, namely, from 8,000 to 8,500 feet, vertical elevation, the angular elevation has ranged from 30° to over 40°, and the length of line employed from 11,000 to 13,000 feet. The pull has ranged under these circumstances from 50 to 80 pounds.

The elevation of the kite is determined from the measured angular elevation of the kite and the known length of line out. A correction is made for the sag of the wire, which is shown by the difference between the angular elevation of the kite and the inclination of the wire at the reel. These two angles are the same if there is no sag. The correction varies from a few tenths of a per cent. to over 2 per cent. of the total length, and is computed from the equations of the catenary on the basis that the curve assumed by the kite line is a simple catenary. This neglects the effects of the lateral pressure of the wind on the wire, which is very appreciable, and no doubt modifies the curvature of the wire considerably. The error of the computed percentage of sag on this account is, however, of slight importance.

The angular elevation of the kite is determined by means of a nephoscope,* an instrument ordinarily employed for measuring the angular position of clouds and their apparent motions. The instrument is shown in *Fig. 5*, and consists, essentially, of a mirror mounted on levelling screws, with an adjustable sighting staff. A fine thread fastened to the topmost point of the sighting staff passes through a fine hole in the center of the mirror and is kept taut by means of a small plummet below. To make an observation, the image of the kite in the mirror is brought to the central point and the sighting staff adjusted until the image of the knob coincides with that of the kite. The angle between the thread and the mirror, that is, the angular elevation of the kite, is then measured by means of a protractor, graduated to half degrees. The accuracy attainable with this apparatus suffices for all ordinary ascensions

* *Monthly Weather Review*, U. S. Weather Bureau, Vol XXIV, 1896, p. 10.

where the movement of the kite itself prevents the most exact measurements. In high ascensions a theodolite or sextant is required, and both have been largely used in the work at Washington.

The Meteorograph.—Manufacturers of meteorological instruments have not yet put on the market any good form of kite meteorograph, that is, an apparatus light enough to be

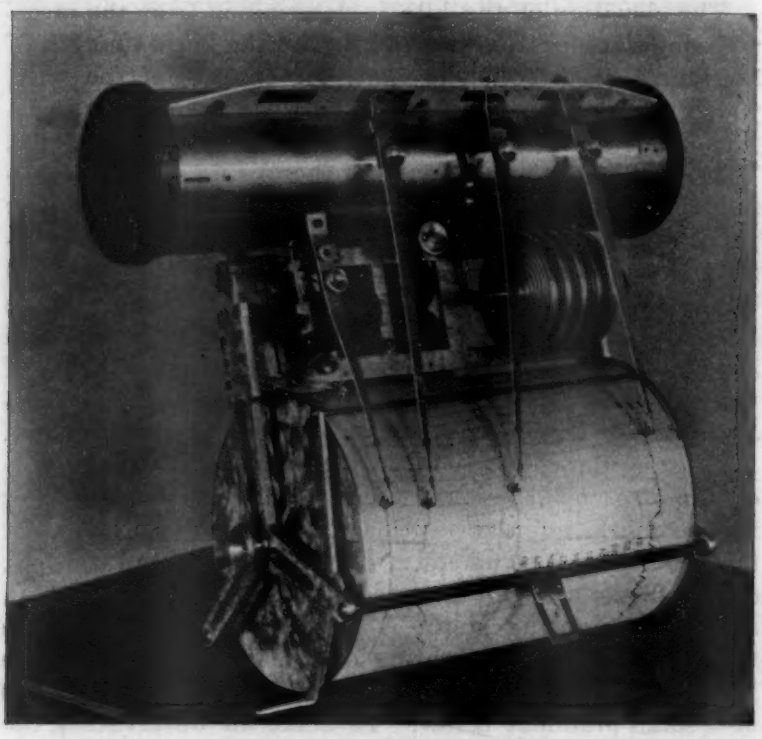


FIG. 6.—Marvin meteorograph.

carried aloft by kites and adapted to automatically record the desired meteorological elements. The meteorograph shown in *Fig. 6* and employed in the Weather Bureau work was constructed by a New York manufacturer, in accordance with designs and specifications furnished by the Bureau. The instrument records four meteorological elements on the same sheet of paper, which is wound around a

suitable cylinder moved by clock-work inside. Ordinarily the speed of rotation of the cylinder is one revolution in twelve hours; that is, one inch on the sheet per hour; but, for testing purposes, the simple tightening of a nut enables one to change the speed to one revolution per hour.

The pen at the extreme left in the picture records the wind movement by means of a small anemometer attached to the kite. Thus far, the anemometer has been used only on the kites at Washington.

The next pen in order records the temperature of the air; the third pen the pressure of the air, and finally, the pen on the right side of the picture records the percentage of moisture in the air.

When the instrument is attached to the kite, the wind blows with full velocity through the long tube seen at the top of the picture, thereby causing the thermometer bulb and hair hygrometer exposed therein to take on as perfectly as possible all the successive atmospheric conditions. Not only does this arrangement secure the most satisfactory ventilation for the thermometer and hygrometer, but it also completely screens them from direct sunshine. Hard-rubber rings at the ends of the tube, and strips of ivory extending lengthwise, prevent any direct metallic contact between the long tube and the outside case of the instrument, thus cutting off any heating of the thermometer by the action of sunshine on the case.

The thermometer bulb consists of a pair of Bourdon tubes filled with alcohol. The tube is ellipse-shaped, in cross-section, but very sharp at the ends of the long diameter. The major and minor axes of this ellipse are about $\frac{9}{16}$ and $\frac{1}{16}$ of an inch, respectively. The thickness of the metal is only about nine thousandths of an inch. These tubes, closed at each end, are formed into nearly a complete ring $1\frac{1}{2}$ inches in diameter, and completely filled with alcohol, so as to perfectly exclude all the air. The short gap between the ends of the tube is opened beyond its natural width by a wedge, or otherwise, while the alcohol is being introduced, and the tube is then hermetically sealed by soldering. By this procedure a state of internal stress is set

up in the tube, when the wedge is removed, and the ends, by the elastic action of the metal, tend constantly to approach each other, but are prevented from doing so by the alcohol, except as it contracts in cooling, or spreads the ends still further apart on expanding. This type of thermometer has been extensively employed in thermographs, but heretofore the bulbs have been made only of brass, or composition metals, the elasticity of which is so imperfect that the best results cannot be secured. The tubes in the Weather Bureau instruments were made of carefully tempered steel, the elastic reaction of which was practically perfect. Two small tubes are employed in each thermometer, instead of one larger one, in order to secure the highest practicable degree of sensitiveness. Carefully conducted tests show that under the conditions arising in practical work, that is, when the kite rises or falls rapidly through successive strata at different temperatures, the lag of the thermograph is only about 1° F., when the air temperature steadily changes at the rapid rate of 1·5° per minute. Ordinarily, this would correspond to a rise or fall of the kite of nearly 500 feet per minute. Experience has shown that the thermographs, as ordinarily constructed by manufacturers, are entirely too sluggish for satisfactory results in kite work.

The registration of pressure is effected by the well-known aneroid barometer mechanisms. The inherent errors of this type of apparatus have been extensively studied and are well known to careful investigators in these matters. Thus far, no maker has been quite successful in eliminating a considerable error due to the imperfect elastic qualities of the metal of which the vacuum chambers are constructed. Usually, brass, or similar composition metal, is employed. The aneroids in the Weather Bureau meteorograph were, however, made of steel, the more perfect elastic properties of which it was expected would contribute better action. This was shown to be true by careful tests of similar barographs of steel and brass chambers. The difficulty was not removed, however. The absolute errors are, in fact, quite small, but the study of atmospheric phenomena requires a

very accurate measurement of pressure, and errors of $\frac{1}{10}$ of 1 per cent. are of importance. Recent studies of the errors of aneroid mechanisms have indicated directions in which still further improvement is possible.

The hair hygrometer is about the only type of hygrometer that seems practically available in the construction of a kite meteorograph, but it is, nevertheless, not as sensitive and reliable as we desire. Ten minutes or more are required for the hairs to show a change of 10 per cent. in the humidity. Aside from this sluggishness, the indications of the instrument are not wholly reliable and should be frequently checked and verified by comparison with readings of the wet and dry-bulb thermometers.

The greatest need in kites for future work is a more perfect means of automatic adjustment to extremes of wind velocity and considerable reduction in weight of the structure so that better ascensions can be made in light winds. The remarks already made in respect to the errors of the recording instruments indicate the nature of improvements required therein.

Stated Meeting, Tuesday, January 24, 1899.

THE PRACTICAL APPLICATION OF ELECTRIC MOTORS TO PRINTING PRESS MACHINERY.

BY W. H. TAPLEY,
Chief Electrician, Government Printing Office, Washington, D. C.

The past five years have seen marked advancement in the transmission of power by electricity.

Aside from long-distance transmission and railroad work, no branch of the art can show such substantial results as have been accomplished in the field of individual motor application. In this latter the application of the electric motor to printing press machinery has produced results in power saved, improved product and increased output sufficient to cause every large printer to-day to look upon electrically-driven printing presses as a necessity and not a luxury.

Passing by the early arguments used for adopting the individual motor, the engineering problems of what is the best and how shall it be applied are now ready for consideration.

It will be necessary to subdivide the subject, considering each separately, afterwards drawing conclusions from facts submitted.

The following is the definition of "geared" and "direct" motors:

Geared are single reduction motors.

Direct have the armature of motor keyed to the main driving shaft of press.

MAIN TOPICS.

Types of motors, attachment, control, protection, maintenance, cost of operation, advantages, a few facts of the power consumption of the government printing office.

These headings are themselves subdivided.

Types of Motors.—There are three kinds of motors used in printing press work, viz.: series, shunt and compound wound.

Series Motor, owing to its speed varying directly as work done, gives an unsteady and jerky motion to press, which interferes with securing the highest grade of press-work.

Shunt Motor, while giving much better results as to constant speed at all parts of the stroke of the bed of a press, is lacking in starting torque so essential in handling a press during "make-ready," as well as starting the press from all positions of the bed.

Then if lead of brushes is altered to overcome sparking, there is a corresponding change in speed of press shaft.

This fact the pressman sooner or later will discover and more than likely take advantage of on hurried work, ex cessive sparking from a distorted field causing him but little worry.

Compound Motor gives by far the best results for printing press work, having a stiff starting torque, constant speed and minimum sparking at moment of reversal, a constant factor in this class of work.

The commercial demands are for a tough motor, one built to withstand rough handling, overloads, long strains of work, not similar to pumps or blowers, which is constant, but the continuous starting and stopping, reversing, producing conditions which can only be met by a motor mechanically and electrically rigid in all its details; one free from repairs, always ready to be pushed to its maximum.

Sizes.—Motors should always be sufficiently large to handle the presses to which they are attached without straining, and wound for highest efficiency at 70 per cent. of rated output.

For example, suppose we have a 5 horse-power motor attached to Huber press, bed 42 x 52 inches, running at 1,300 impressions per hour, printing 32 pages solid matter, using book ink and running under favorable conditions, the current consumption fluctuating from 12 to 30 ampères at 115 volts; allowing 8 ampères per horse-power, we have, for a 5 horse-power motor, 40 ampères, 70 per cent. of which is 28 ampères.

This press will take to start, varying according to position of bed, from 35 to 50 ampères at 115 volts.

From these figures it is seen that the press is handled promptly and properly, with ample margins, without using too large a motor.

These figures apply to presses that have been in operation some months, not to those newly installed, for often these will demand double the figures mentioned until they become "limbered up," during which time the motor will have a little extra work to perform, but a good motor will withstand this ordeal without harm.

In selecting the size of a motor, do not figure too close; get one sufficiently large to do your work without loss of time to the operator.

The price of motors is not direct as the horse-power, a 5 horse-power costing only about 15 per cent. more than a 3 horse-power motor, while you obtain 66⅔ per cent. more power.

The efficiency of a 3 horse-power and 5 horse-power

motor, both running under load of 2 horse-power, will be within 2 or 3 per cent. of each other, thus placing each on substantially the same basis as to commercial efficiency.

This reserve power will prove a valuable source of revenue before the year is closed.

Belted, Geared and Direct-Connected Motors.—The main advantages to be gained from the individual application of electric motors to printing press machinery are steadiness of power as applied to main driving shaft, absence of overhead belting, economy of floor space, increased output and ability to place presses in a room irrespective of a main line of shafting.

The main difficulty with belted motors is the slippage of the belts, which frequently causes poor register and slurring; with overhead belting this is further increased from dust, dirt and scales, which are constantly given off from the surface of the belts, battering plates, and the obstruction to light in the room all tend to decrease the output.

In fact, the belted individual motor has only two advantages over the main line driving, viz.: Location and independence of main line, in case anything happens to belting which might necessitate shut-down of all the presses.

As it retains all the disadvantages of the main line drive, it should be discarded where good work is wanted.

The geared and direct-connected motors only will hereafter be considered.

To reach a conclusion as to which is the better will, in most cases, necessitate an individual consideration, first, by the electrical engineer and the press builder, and, finally, by the proprietor, who pays the bills.

The principal features of each should be considered separately.

Geared Motor.—This must be of moderate speed, not of a high speed, for then the reductions, motor to press, are prohibitive.

Speeds should be from 1,000 revolutions per minute for 1 horse-power, to 500 or lower for 15 horse-power; this will permit of a suitable mechanical reduction and attachment to presses whose main driving shafts vary in speed from 90

to 175 revolutions per minute. When this is exceeded, it is almost impossible to make the press—one of the large types—run quietly, and if noise is an objection, the direct-connected type becomes advisable.

Hardly any two makes of presses have the same shaft speed, nor are the diameters of shafts the same; so for presses of same sized bed and production there is required for each make of press different ratios of reductions, which can be easily supplied by gearing, always using the standard motors.

While with the direct-connected motor, the armature, being keyed to press shaft, must be built especially for this individual type and make of press.

Its interchangeability with other presses of different manufacture is a great rarity.

If press is sold or replaced by another, the motor must be made over to suit, or else thrown away, while the standard geared motor is always ready for use with a change of gearing.

The ratios in presses vary from 4 to 1 to as high as 12 to 1.

Press ratio means for every 4 or 12 revolutions (as case may be) of press shaft there is made one impression.

In some cases the geared motor takes up more floor space than a direct-connected, but not always, notably in the stop-cylinder type, which has driving shaft at the rear of press, enabling motor to be placed under the delivery table, reducing the floor space even of belted presses.

Should trouble occur to the "direct" it is much more serious, for this means a shut-down of the press, until injured parts can be repaired or furnished by factory.

Waiting for special made motors to be repaired or rebuilt is very tiresome, as those of us know who have to place ourselves at the mercy of manufacturers.

Duplicate geared motor armatures can be kept on hand and change made easily during "make-ready," with no loss whatever of production.

Owing to the wide variation in speeds, bore of shafts, it is impracticable to keep on hand "direct" armatures; cost

is prohibitive to keep a special armature for each size press.

Increased cost of direct over geared is from 25 to 33⅓ per cent. for new presses as they come from the factory; cost of installation about the same.

Difference in cost of electrically equipping presses already supplied with belting depends largely upon circumstances, whether shaft has to be lengthened, turned off, etc.; but cost is nearly equal if gearing has to be bought and pulleys cannot be sold.

These figures refer to motors of about 5 horse-power and speed 175 revolutions per minute and up; smaller sizes, as well as lower speeds, make material advantages in favor of geared motors.

Voltage should be either 115 or 230. Five hundred volts is too high to have about so much metal which employees are constantly touching.

Attachment.—I wish to call particular attention to this part of the subject under consideration, for it is one that the electrical engineer is more likely to slight, it being wholly mechanical engineering.

First, in every case make the motor part of the press; it must *not* be placed on a separate foundation; it is absolutely essential that this be rigidly adhered to in all cases where satisfactory results are expected, for otherwise the gearing will get out of line. In the case of "direct" motors, there is liability of the armature hitting against the pole pieces or else bind the main press shaft sufficiently to get a hot box and cut the shaft.

Next in importance is to provide a proper foundation; in most cases up to 3 horse-power, an iron bracket of sufficient strength, securely bolted to frame of press, will meet all the requirements; in all sizes from 5 horse-power and upwards, an extension of masonry foundation on which press rests should be made; cast-iron motor base must not only be bolted to press, but anchored to the masonry foundation by grouting in cement or with anchor bolts—in many cases both should be done, thereby obtaining a foundation amply massive to take care of all the jars and strains to which

the motor will be subjected, without running the risk of loosening the bolts in foundation and getting motor out of line.

In a "Huber" press, running at a speed of 1,500 impressions per hour, the bed is travelling at the rate of 300 feet per minute; weight of bed, with form, over 1,000 pounds; a total of over 300,000 foot-pounds to take care of, while the press is running at full speed within a bed travel of 4 to 5 feet, with reversal following immediately. To cause a more sudden stoppage would be disastrous to the machinery of the press.

The rough usage to which the electric motor is subjected on presswork is such that if repair bills are to be kept down, the initial cost must not be the sole guide.

In the case of direct motors, the outboard rigging makes it much easier, at the same time presenting a more graceful appearance when finished, to attach motor to press without either foundation or motor sub-base. In this case the supporting brackets must be rigid and bolted to press with a "driving fit," for, when play is left in bolt holes, trouble is sure to arise sooner or later from the motor shifting its position.

Even with direct-connected motors, it is best, wherever possible, to provide a sub-base, for reasons mentioned in connection with geared motors, as well as the assistance received during installation. The proper handling of motors weighing from 500 to 1,100 pounds, while working to a "driving fit," with the ordinary appliances at hand in a printing office, is not rapid or satisfactory work.

Gearing should consist of rawhide pinions with cast-iron gear wheels, being sure to have both pinions and gear wheels cut by the same factory. Having rawhide manufacturers cut the pinions, and press builders or some other machine shop cut the gear wheels, invariably results in noisy running gears. Engineer should give personal attention to this when installing work.

The gear wheels should be fitted with taper bore, keyway and cap on end of shaft. The use of set screws is not satisfactory.

The pinion should be of the best grade rawhide, having brass sides and sleeve, latter thicker than depth of keyway. Face wide enough to allow for armature vibration, without metal sides running on face of gear wheel.

Teeth should not be too fine pitch. My experience has been that, for ordinary work, a 4-pitch diameter tooth is thoroughly satisfactory, showing little wear after continuous use for several years.

On heavy presses it is advantageous to connect, by means of a stiff wrought-iron bar, the press and motor bearings.

Satisfactory ratios of reduction, motor to press, from 10 to 1, desired speed not exceeding 120 revolutions per minute; 5 or 3 to 1 on higher speeds. These will run well, and with little noise or wear, for several years.

Great care must be exercised in selecting the workmen that are intrusted with the lining of the gears; this is one of the most important parts of the installation of the electrical equipment, and should be intrusted only to trained experts in this class of work.

Position of Controller.—In attaching the controller to the press, care and judgment should be exercised to place same so that the handle is convenient to the press feeder, the direction being away from the body while starting press and towards the body to stop, which at times must be done immediately to prevent sheets getting on the roller, etc.

This should be fastened to a cast-iron bracket, when possible; otherwise, wrought-iron supports well braced will answer.

Wiring demands high-grade insulated wire, so protected that it cannot meet with mechanical injury.

The hanging of wires from the ceiling should not be permitted, as it is not safe, at same time interfering with the proper handling of the press.

On most presses the feeder is on the opposite side of the press from the motor, therefore, wires must be run across press to same. About a press is much oil and ink, all detrimental to the insulation of the wire, which must be kept perfect to insure uninterrupted use of the press. This can be secured by using highest grade rubber wire, taped and

braided, enclosed in a continuous length of flexible tubing, these finally encased in black iron pipe, said pipe to be firmly bolted to press, if running across, or cemented into foundation with painted joints if running underneath press. If this method is adhered to, the thought of ever having trouble from your wiring may be placed to one side.

Personal experience has shown that, where this method has been followed, we have never had a leak on our wires.

The knowledge that wiring when once installed is perfect and will give no trouble is fully appreciated by the engineer in charge, and will be by the proprietor, after a few *expert* bills for testing wires have been paid.

Keep controllers and rheostats as far away from the floor as possible; they will be kept cleaner and are less liable to damage from scrubwomen and trucks than if placed on the ground.

Control is a subject to which more care and thought has been devoted by electrical engineers than all the rest of the equipment combined.

A casual glance at what is necessary to properly handle a printing press before starting to print will disclose the problems which had to be solved. Take a large flat-bed two-revolution press, bed 42 x 52 inches, or one large enough to print 32 pages 16mo at an impression, as an example. Starting from the "make-ready," when the pressman places the form on the press and begins to see what is necessary to produce good work. In placing "overlays" on the cylinder, the press is moved a few inches forward, then reversed, or the cylinder is turned ahead a half revolution, then reversed a quarter, etc. In placing plates on the press, many times the bed is needed to be moved not over an inch or so; all this must be done quickly and absolutely, for unless the press is under perfect control an accident may easily occur. The more perfect the control, the less time is the press idle and becomes a wage-earner instead of an interest-eater.

After the press has been started and working satisfactorily, absolute control must continue, as there will be occasion to stop same quickly within stroke of bed or even less;

this must be while under full speed and in such a manner as not to jar or injure the press.

Speed Control.—There are several methods in vogue at the present time, viz.: Resistance in series with armature, commutated field, field control by insertion of resistance, combination of resistance in armature and resistance in series with field, having the former take care of about two-thirds range of speed, then depend on weakening the field for the balance.

The latter method gives the widest range of speeds and for direct motors is the most satisfactory to install, both to seller and purchaser.

Most every engineer, without exception, cries down the armature-resistance method as grossly extravagant. On the surface, or from a theoretical standpoint of the motor itself, this is correct, but what are the facts in actual practice?

In most large offices certain presses are used on work which requires nearly always the same rate of speed, although the character of the work may not be uniform. These presses can be fitted with gearing suitable to give proper speed when motor is "full on," using the resistance only as a starting medium, rather than a speed regulator.

To convince myself what the actual difference was in commercial work, I conducted experiments and tests, lasting over six months, taking geared motors with armature control, and "direct" having commutated field.

Method of test was as follows: To each press was attached a "Thomson Recording Wattmeter," carefully calibrated. Readings were taken daily. The output was taken from the daily report of pressman to foreman of the press-room.

These were all attached to same size and make of press, doing regular bookwork. From day to day there were some striking differences, yet at the end of each month and the close of the six months' test the armature control held its own, showing an efficiency not usually accorded to it.

The following is the test in detail:

OUTPUT AND POWER CONSUMPTION, HUBER PRINTING PRESSES (BED, 42 x 52). JULY TO DECEMBER, 1897. GOVERNMENT PRINTING OFFICE.

No. of Press.	Watt Hours Consumed.	Work Done, Impressions.	Watt Hours per Impression.	Type of Motor.	Method of Control.
4	1,055,400	788,843	1·337	Direct.	Commutated field, compound.
5	832,700	572,991	1·453	"	Resistance in field, shunt.
6	1,152,800	766,512	1·503	"	Commutated field, compound.
7	861,200	436,552	1·972	"	"
8	998,800	525,010	1·902	"	"
9	777,600	487,306	1·595	"	"
10	1,265,700	729,986	1·733	"	"
11	1,274,000	754,884	1·687	"	"
12	931,300	563,731	1·652	"	Commutated field, series.
13	1,250,100	606,247	2·062	"	"
32	819,400	593,854	*1·379	Geared.	Resistance in armature, compound.
33	975,200	474,170	†2·056	"	"
34	1,025,600	650,046	1·577	Direct.	Resistance in field, shunt.
54	1,273,000	739,903	1·720	Geared.	Resistance in armature, compound.
65	1,411,200	809,219	1·743	"	"
67	899,984	579,646	1·552	"	"
69	1,115,200	707,100	1·577	"	"

* Maximum speed of press, 18 impressions per minute.
† " " " " 25 " "

This clearly shows that the geared motor with armature control is not a back number. No law or rule can be given as to which is the most economical method, owing to the wide range of conditions entering into the solution of each problem; this should be intrusted to a competent engineer to decide.

Adherence to simplicity, avoiding all complicated methods of control consistent with economy of current consumption, produces the most satisfactory commercial conditions.

Controller should be of the barrel type, compact, having all contacts inclosed and protected. This should be provided with only *one* handle, and having five or six speed contacts with two points reverse. The necessity for limitation to one handle is that two will produce confusion

when quick action is required; if operator is told to do this and then that, he generally does that, then this. With one handle a demand for instant reversal is quickly responded to, as there is but one thing for the operator to do—*i. e.*, push the handle in the opposite direction from existing conditions. This very soon becomes instinct with the press-feeder and mistakes are unknown.

The controller should be so made that it can be easily repaired and inspected, provided with ample carrying capacity and liberal surface contacts, allowing not more than 40 ampères to square inch; cylinder should be convexed and fingers concaved; where large quantities of current are to be carried by fingers, the latter should have copper braid connecting tip with base; larger size controller should be provided with special contacts for breaking current, not depending upon them to carry current while in constant service—this will reduce heating to a minimum; it must be easily handled and free from breakdowns.

When a first-class controller has been produced, the manufacturer has won half the battle, for herein has been one of the greatest sources of trouble the printer has had with individual motors, viz.: getting suitable control coupled with a substantial and reliable controller.

Reduce all automatic devices to a minimum, if not dispensing with them altogether on the controller; they are unnecessary, and as such are sources of trouble. A quick brake reduces sparking, thus lessening the chances of undue heating of contact fingers while in use—its adoption is an advantage.

Push buttons about a press, which is hand-feed, are superfluous and should only be used in connection with automatic feeders.

The great range of speed stipulated by some is seldom used in actual practice; ranges of running speeds from ten to thirty-five impressions per minute, as I see discussed, are so rare in large commercial houses as not to be worthy serious consideration. Cut work is not done at the high rate of speed of common job presses, nor are the same presses used for both classes of work and expected to pro-

duce the best results. Running the press at high rate of speed would soon make it unfit to do first-class half-tone work upon. And running common job printing on slow-speed cut presses would not pay. What is necessary in determining the range of speed of a press is the knowledge of the class of work to be done most thereon and how it is to be fed. A general knowledge of presswork and common sense will, as a rule, settle these problems satisfactorily.

If extreme limits are insisted upon, the proprietor must suffer and take what he can get as to economy and first-class work.

Protection includes a larger field than the electric motor—the printing press and operator should be fully considered.

Experience has developed the fact that satisfactory protection is secured only by means of an automatic circuit breaker; this applies not alone to the motor, but the printing press and its operator as well.

In the individual application of the electric motor, in most cases, the price of the motor is small, compared to the machine to which it is attached. For instance, the cost of an ordinary two-revolution front or back delivery flat-bed press, book size, is about ten times that of a first-class electric equipment for same, installed complete in every respect.

The motor will stand more rough handling than either the printing press or the operator, and still be in condition to do its work properly, conclusively showing that more than the protection of the motor is demanded. The results of the exclusive use of circuit breaker for printing press work are the reduction of repairs on presses 50 per cent., stoppages practically eliminated, with prolonged life of machinery. Presses can be handled promptly from any position, with circuit breaker set at 50 per cent. above capacity of the motor, providing the press is in free running condition; if it is not, the circuit breaker is the best tell-tale extant. The failure of the pressman to properly clean and oil his press is followed by a frequent opening of the circuit breaker, showing something is wrong and needs attention.

A personal experience in this line may help to explain more clearly the point in question.

Shortly after equipping some of the first presses in the office, constant complaints were received from one especial press, that the motor was not working satisfactorily, power unsteady, press would not start unless assisted by a laborer, circuit breaker was a nuisance, as it opened constantly. This continued until the press refused to work at all—motor was unable to turn it over. Investigation showed the main press shaft to be fast in its bearing, the pressman having failed utterly to oil or care for the press.

Henceforth we were not in receipt of complaints from that press; the ability of the circuit breaker to show up so clearly carelessness on the part of the workman established for itself a reputation which is still of the highest.

Injuries from rough handling and sudden starting are very materially eradicated. The impact from a blow four or five times the capacity of a motor, which a fuse permits, must expend itself somewhere; if it does not break a part, it strains the entire press, and constant repetition means lost motion in running gear—this is fatal to good printing.

This was such a serious objection to the individual connecting of electric motors to printing presses, that one of the oldest and most prominent press builders in this country came out flat-footed against this method, and said we must have a belt as a driving gear, for this would slip or run off the pulley; gearing meant the wreck of the press if anything went wrong. They were right when fuses were the only method of protecting the press, as they were not quick enough to prevent trouble. But with the use of a reliable circuit breaker all these objections are swept away, and we have better protection a hundredfold than slipping belts.

One word about the protection of the employés before leaving this subject. Carelessness bred by familiarity is the great source of danger to the majority of employés, and lessening of results from this demands thoughtful consideration. By way of illustration I will narrate two such instances, which have come under my personal observation.

(1) A laborer was cleaning a press, while in motion, with cotton waste; this caught in the gear wheels, drawing in his hand. The circuit breaker opened promptly, owing to the increased power necessary to overcome the resistance of his fingers between the gears. The press stopped before the entire hand was drawn into the moving machinery—three fingers only being hurt, one sufficiently to need amputation. Had fuses been the protection instead of a circuit breaker, nothing could have saved this man's entire right hand.

(2) A young lady passed too close to some moving machinery—a place where all passage was prohibited, on account of the closeness of rapid-moving presses—her dress skirts in some manner became entangled in the moving gear wheels, drawing her over against the machine; the quick opening of the circuit breaker stopped the press, with a result to her of a torn dress and a nervous shock.

The results which would have occurred in both instances, had circuit breaker not been in use, are sufficient to justify the employés in expecting that the highest type of protective devices will be used wherever possible.

The flexibility of the circuit breaker, in that it protects more than the motor, saving during the year in repairs more than its cost, clearly shows that it is a wise investment.

When installing an individually equipped printing press, the printer should insist on its use.

Maintenance.—Under this heading offices of reasonable size only will be considered, also assuming that presses are in constant use. Here the most satisfactory course to pursue is to have the care, inspection and responsibility of maintenance located at one source. One man should be intrusted with this work; a little study in systematization will accomplish all this while presses are "making ready," or at least so as not to interfere with work of production.

Inspection once in two weeks or once a month will do, in offices not too busy; this will keep down repairs, and, most important of all, keep the plant in A1 running condition, ready for anything.

Leaving care of motors to pressmen and laborers is a bad practice for everyone but the repair man. Not alone will the repairs increase, but, most serious of all, the press stops earning money when out of order, and at $10 or $15 a day this becomes expensive.

A good man who is able to turn off commutators, keep controllers in order and has a general idea of the electrical and press equipment, will pay for himself many fold during the year.

Small offices, like our branch offices, we look at once in two months.

Cost depends on what you are able to secure the services of such a man for—$2.50 to $3 per day.

Records should be kept of all repairs made and material used, if exact cost of maintenance is desired. This provides means of tracing where delays occur, whether in press proper or its driving motor.

Cost of Operation.—Herein figures can be used to obtain nearly any result desired, unless we demand full particulars, necessitating elaborate statement of all existing conditions. Having made most careful tests, the manufacturer cannot be guaranteed that his plant will operate within test figures, unless all conditions in commercial work are similar; these are impossible, so we are forced to make a test covering months of work, striking a balance from the results obtained; these will give average commercial figures, which in most cases will show an increase over a short test under favorable conditions.

To realize how much depends on the pressman, I desire to call attention to some facts with regard to two new presses recently installed in our office. These were "Century" two-revolution front delivery, bed 43 x 56 inches; connected to each press was a C-W, 2-100 compound motor, speed 130 to 230 revolutions per minute.

All went well for a month or so, then complaint was made that one of the presses ran slower the longer it was in operation. An examination disclosed the fact that the motor was apparently not large enough for the press, as the fields and frame became so warm that the hand could

not be held on it for any length of time. Speed dropped from 180 to 140 revolutions per minute, after which circuit breaker was constantly opening, and it became necessary to shut down press every two hours or so that motor might cool off. A test showed that the press took 46 ampères at 120 volts; speed, 144 revolutions per minute; this was on fifth speed; moving handle to sixth and last point with circuit breaker set at 58, latter would open every time; this was reset at 70, and ammeter indicated 60 when change was made to last speed; current used, 48 ampères at 160 revolutions per minute. Press labored and did not run smoothly.

On examination, we found that the track gibbs had been set up too close; after properly adjusting these and having press thoroughly oiled, we increased speed to 180 revolutions per minute, current consumed dropped to 30 ampères; even then the press was stiff, for its companion was running at 182 revolutions per minute on 22 ampères, both doing same class of work.

This showed the press was taking 60 per cent. more current than it should had only ordinary care been used, while it was consuming 100 per cent. more than its duplicate, working under similar conditions.

A commercial figure ought to show an increase of 15 to 20 per cent. over efficiency test.

A hurried glance at the comparative cost of operating belted, geared and direct-connected motors is desirable, although a complete analysis is impossible to include in this paper owing to its length.

Belted motors, unless grouped, will not be considered, as they have no commercial standing for economy.

First, considering grouped presses of medium size, running from main line shaft, driven by a single motor. A line of drum cylinder presses of various makes, operated by belting afterwards driven by individual motors, gives actual commercial condition worthy of comparison. Taking, for example, thirteen drum cylinder presses in a row, with belting reduced to a minimum, a large motor belted to center of shaft, thus distributing load equally on hangers;

using a 15 horse-power motor, so with all presses at work motor is running at about 75 per cent. load—very favorable conditions.

During two months these presses made 2,892,175 impressions, consuming 1,601,200 watt hours, or an average of ·553 watt hour per impression.

As soon as possible after equipping these presses with 2 horse-power geared motors wattmeter records were taken. For four of the heaviest running presses, a six months' continuous test showed the following:

Impressions, 3,813,542. Watt hours, 1,851,100, an average of ·485 watt hour per impression, a saving of 14 per cent.

While disconnecting presses one by one, to equip same individually, the average consumption per impression for the remaining presses increased very rapidly. With five presses working we used between 50 and 60 per cent. more current per impression.

Geared vs. Direct shows that up to 5 horse-power the geared is more economical. In 5 to 15 horse-power, there is not much difference. Economy of operation should not be the guiding spirit in the selection of motors of these sizes. From 25 horse-power up, the direct motor has many advantages, especially for newspaper work.

Cost of Presswork.—A web press, printing at the rate of 6,000 impressions per hour—this includes cutting, folding and printing four signatures of 16mo or 64 pages, including all stoppages—will produce in a day 2,304,000 pages, an average of 384,000 pages for each hour. The average current, including "make-ready," etc., is ·7 watt hour per impression; 91,428 pages per hour per kilowatt; at 5 cents per kilowatt hour, there will be printed, cut and folded 18,285 pages for 1 cent.

A good day's work for a flat-bed press, bed 42 x 52 inches, running at 20 impressions per minute, is 8,400 impressions in eight hours, of 32 pages each, with a total of 256,000 pages for the day.

Average current consumption is 1·5 watt hours per impression, or 21,333 pages per kilowatt hour; at 5 cents per kilowatt hour is produced 4,266 pages, as against 18,285 by

the web presses for the same money (1 cent), making an output for the webs four and one-half times that of the flat-bed presses, with same current consumption. The quality of the work of the former is not always as good as the latter, yet is more than compensated for by the folding and cutting.

A card-press, which prints both sides, making slitting and cross-cut from a web of cardboard, is not a usual press. The following is the output and power consumption for five months:

Impressions	8,362,750
Kilowatt hours	580·6
" " per impression	·0694

Four cards being printed at each impression, there was a total of 33,451,000 cards. With current at 5 cents per kilowatt hour, 11,500 cards were printed for 1 cent.

Main Pressroom, Government Printing Office.—In this room are forty-nine presses, including three large web presses; of the balance one-half are large-size book presses, the remainder of double-medium size, attached to which is an aggregate of 190 horse-power in motors.

During the month of November, 1898, the presses made 5,403,032 impressions, consuming 6,542·8 kilowatt hours, an average of 1·21 watt hours per impression.

6,542·8 kilowatt hours at 5 cents, $327.14; or 165 impressions, allowing 12 pages for each impression, we have 2,000 pages for 1 cent.

Power Plant, Government Printing Office.—The entire power, exclusive of heating, lighting, fans, etc., consumed during the month of December, 1898, from 8 A.M. to 4 P.M., during 27 working days, 22,516 kilowatt hours, 834 kilowatt hours per day, or 104 kilowatts per hour. Connected to the power circuits are 700 electric horse-power, including electric elevators; 575 electric horse-power, without electric elevators. Daily consumption is about 100 kilowatt hours for elevators, thus giving the following ratios:

5·1 horse-power connected to power used.

6·2 horse-power connected (exclusive of elevators) used.

Largest swinging power load we have ever had is 180 kilowatts, or a ratio of 2·9.

Current consumption during November, 1898, for foundry, 3,025·2 kilowatt hours, average 12·2 per hour; folding room, 1,295·8 kilowatt hours, average 5·4 per hour; bindery, 1,875·2 kilowatt hours, average 9·7 per hour.

Advantage to be gained from changing over from belting to individual electric motor for printing-press work is not alone in power saved, but better grade of work, less spoiled sheets, cleaner, healthier rooms for employés, less repairs to machinery, and, most of all, an increased product without a corresponding decrease in value of presses by running at too high speed.

Output of the government printing office pressroom has been increased 15 per cent. A few calculations will show what this means in an establishment operating continuously 100 presses, each earning, at the smallest figure, $10 per day, or $300,000 for the year. 15 per cent. of this is $45,000, a sum that makes the saving in motive power dwindle into insignificance. A few years will pay for the entire electric equipment, including the lighting.

If there is any printing office in the country where a reliable power must be had, it is the government printing office. We run 24 hours daily during Congress, and keep lights going throughout the year, never shutting down our power plant. We issue a daily paper, the *Congressional Record*, having to catch mails same as any other daily. Then all bills introduced, together with the proceedings of Congress the day before, have to be on each member's desk by 10 A.M. To this must be added the printing furnished the various branches of the government, consuming a daily average of 25 to 30 tons of paper.

Our recent war with Spain has made demands in excess of anything heretofore.

At the end of the recent popular bond issue, the Treasury Department wanted 2,000,000 copies of circulars Monday, copy for which was received late Saturday. They had wagon-loads waiting at their doors Monday morning. This is but one instance of many we have been called upon to execute.

There has never been a hitch in the motive power; not a motor has given out. In fact, such a freedom from interruption of power has never been known in the history of the office as during the past three years, or since we have adopted electric power.

The most brilliant achievement during the year was the printing of the "Maine Report." "This consisted of 298 pages of text, twenty-four full-page engravings and one lithograph in colors, and although the originals of the illustrations were not in the possession of this office until 3 o'clock P.M. of March 28th, and the manuscript of the text was not received until 6 o'clock P.M. of the same day, complete printed copies, in paper covers, were placed upon the desks of Senators and Representatives by 10 o'clock of the following morning."

In the treatment of this subject, necessarily many times subdivided, I have tried to mention, in a brief way, all essential points, a detailed consideration of which would exceed the limits of this paper, yet hope in the future, at your discretion, that these may be clearly explained by illustrations and carefully prepared tables of data now in course of compilation.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 19, 1899.

IMPROVED METHODS FOR THE PURIFICATION OF SEWAGE AND WATER, AS SHOWN IN THE OPERATION OF THE MUNICIPAL PLANT AT READING, PA.

BY JOHN JEROME DEERY,
Architect and Engineer, Philadelphia, Pa.

(*Concluded from p. 239.*)

During the winter seasons the plant has been in continuous operation, notwithstanding very hard freezing weather. The temperature has frequently been below zero. Last winter, during the blizzard, the temperature was below zero

for several days, and fell one day to 19° below zero. For thirteen consecutive days it was below the freezing point. On February 10, 1899, the thermometer registered 14° below zero for twenty hours. During the winter, when the liquid is shut off a compartment, and it has percolated through the beds, there is formed an ice coating to columns and girders below it, and from the bottom of the beds icicles become pendant. The surface of the top of the compartment becomes frozen for a few inches in depth. At the same time the lower beds are not affected, as the ice falling into the moving water is broken up and melted. Not a pound of ice has ever been carted away from the plant. All other compartments of upper beds and of the lower beds are working and filtering the water under these and all conditions. The liquid is seldom less than 45° temperature, and when the liquid is distributed upon the compartment out of service, from its warmth it soon penetrates the surface of the bed, and within ten minutes the bed will be running as usual, and all icicles will have dropped into water below on lower beds.

The water then flows from the underdrains or gutters over metal disturbers which further aërates it, and then passes into the broad and shallow cement channel, where in transit for nearly 900 feet it receives the benefit of light and air. Then it discharges through a 24-inch terra-cotta pipe for 1,000 feet into an arm of the Schuylkill River—clear, pure, sparkling and odorless water.

The absolute elements that are essential to perfect water or sewage purification are combined and provided within the plant, viz.: sand filtration by gravity without the aid of chemicals; constant aëration and oxidation; exposure of water in shallow depths to the sunlight; culture beds to promote healthy, active micro-organisms for complete nitrification, or conversion of animal and vegetable matter into harmless mineral matter.

The effluent discharged from this plant into the river, by its varied acts, is chemically and bacteriologically pure to a standard in excess of 99 per cent. over that of the original impure and foul liquids. As at the pumping station, there

is not any offensive or unpleasant odor arising from the operation of the plant.

This process is fully protected by patents in the United States, Canada and European countries, issued to John Jerome Deery, the inventor.

Crude sewage may be applied to this plant at the rate of 12,000,000 gallons per acre daily, undergoing transformation that makes the water of the effluent more pure and wholesome than is to-day supplied as drinking water to most of the cities and towns of the United States and Canada.

The pumping station has been in active operation since February 3, 1896, and the filtration or purification station has been in active operation since November 20, 1896.

THE PENNSYLVANIA SANITATION COMPANY, 1110 BETZ BUILDING, PHILADELPHIA, PA.

BACTERIAL ANALYSES.

Date of Analyses.	Number of Samples.	Different Points During the Purification Process.	Bacteria per Cubic Centimeter.		Percentage of Bacteria at Different Points, as to Number Applied.	Percentage of Bacteria Removed.
			In Applied Sewage.	In Water at Each Point.		
Oct. 9, 1896	1	Crude sewage	27232·8	—	—	—
	2	Sewage through the coke filter	27232·8	19152·4	70·32	29·68
	3	After filtration through upper filter beds	27232·8	516·6	1·89	98·11
	4	After aëration below upper filter beds .	27232·8	126·0	·46	99·54
	5	After filtration through lower filter beds	27232·8	22·0	·08	99·92
Oct. 19, 1896	1	Crude sewage	49867·3	—	—	—
	2	Sewage through the coke filter	49867·3	16542·7	33·17	66·83
	3	After filtration through upper filter beds	49867·3	232·6	·46	99·54
	4	After aëration below upper filter beds .	49867·3	81·2	·16	99·84
	5	After filtration through lower filter beds	49867·3	·2	·0004	99·9996

CHEMICAL ANALYSES.

PARTS IN 100,000.

Date of Analyses.	Number of Samples.*	Chlorides.	Total Hardness.	Oxygen Consumed in the Moist Oxygen Process for Determining Organic Matter.	Free Ammonia.	Albuminoid Ammonia.	Amount of Nitrogen as Nitrates and Nitrites.
Oct. 9, 1896	1	9'	15'54	3'947	'34	'14	'429
	2	6'4	15'54	2'187	'27	'09	'650
	3	6'4	16'095	1'125	'022	'02	'673
	4	6'4	16'65	'937	'019	'015	'787
	5	7'	16'65	'812	'010	'025	'984
Oct. 19, 1896	1	6'5	16'095	16'000	'590	'730	'420
	2	6'5	16'650	4'000	'370	'060	'305
	3	6'5	16'650	2'000	'055	'025	'910
	4	6'5	17'760	2'000	'065	'040	'951
	5	6'5	17'760	1'800	'010	'055	'972

*The numbers are identical with those stated for bacterial analyses, thereby indicating the different points from which were taken these samples.

Remarks.—While the above figures speak for themselves, there is no reason for our not calling your attention to the remarkable reduction in the number of bacteria which the process seems to assure in removing, in the last series for example, over 99'99 per cent. of the bacteria disappear during the purifying process. The chemic study shows the enormous reduction of the free and albuminoid ammonias and the rise of the nitrites and nitrates, thus converting, to a large extent, suspicious compounds into salts of which we feel no anxiety.

Respectfully submitted,

W. M. L. COPLIN, M.D.,
H. F. HARRIS, M.D.

[Compiled from the Report of Drs. W. M. L. Coplin and H. F. Harris, Professors of Pathology and Bacteriology at the Jefferson Medical College, of Philadelphia. (Dr. Coplin is the Chief Bacteriologist to the State Board of Health of Pennsylvania.) The first analysis was made after the plant had been in operation only ten days. The second analysis was made after twenty days' operation, showing increased efficiency with continued use. Attention is especially called to the remarkable showing evinced by the enormous reduction in the number of bacteria present in the sewage at the second analysis, from nearly 50,000 to but a small fraction of 1 to the cubic centimeter.]

CHEMICAL ANALYSIS OF EFFLUENT.

PARTS IN 100,000.

Date of Analysis.	Appearance.		Odor.		Ammonia.		Chlorides.	Nitrogen.		Hardness.
	Turbidity.	Sediment.	When Cold.	When Hot.	Free.	Albuminoid.		Nitrates.	Nitrites.	
Feb 13, 1897	None	Slight	Earthy	Faintly	·0480	·0142	5·76	·2400	·0030	32·0

[Compiled from the Report of Mrs. Ellen H. Richards, of the Massachusetts Institute of Technology, Boston, and chemist to the State Board of Health of Massachusetts.]

The cost of the site for the pumping station was $15,000; the pumping station, including all machinery and finish of grounds, cost $75,000; the site for the disposal plant, with right of way for pipe line, cost $8,725; and the filtration station was fully equipped and completed at a cost of $100.000. The total investment, therefore, was $198,725.

The sets of bacterial and chemical analyses herein contained were made by Dr. W. M. L. Coplin and Dr. H. F. Harris, Professors of Pathology and Bacteriology in the Jefferson Medical College, Philadelphia. Dr. Coplin is the chief bacteriologist to the State Board of Health of Pennsylvania. Chemical analysis was also made by Mrs. Ellen H. Richards, of the Massachusetts Institute of Technology, Boston, and chemist to the State Board of Health of Massachusetts.

After ten days' continuous operation of the purification plant, samples were taken at various parts of the structure. The crude sewage contained 27,233 bacteria to the cubic centimeter, and the effluent, 22 bacteria to the cubic centimeter. Ten days thereafter, or after twenty days' continuous operation, the crude sewage contained 49,867 bac. teria to the centimeter, and the effluent, ·02 bacteria to the cubic centimeter.

It is obvious that when foul house sewage, reeking with all kinds of filth, garbage and wastes from buildings, is converted into pure water, as demonstrated by the operation and analyses of the plant at Reading, the purification

of a polluted river serving as a water supply to a town or city is by comparison a simple and easy problem of solution by this process to produce an absolutely potable, bright, clear, sparkling water, free from all color, sediment and disease-producing bacteria.

The truth of these results and the satisfaction attending them have been verified in various ways by the Mayor, Board of Public Works, City Engineer and Sewer Committee of the city of Reading, Pa., as also by State Board of Health of Pennsylvania, Boards of Health of the city of Philadelphia and of the city of Reading, Pa.

During February, 1897, I noticed that the upper bed had become almost blue and black in colors, and that by placing the nostrils directly under the bed a peculiar odor was apparent. I desired an immediate analysis to learn the component parts of the mass. A covered can was sterilized and a section of the upper bed was lifted out and placed in the can in exact position it occupied in the bed. Within a few minutes a train was boarded to Philadelphia, for the laboratories of the Jefferson Medical College. Doctors Coplin and Harris began at once an analysis. On February 15, 1897, they reported that "each gram contained 18,581 bacteria, that 33 per cent. are moulds, 22 per cent. are growth of hay bacillus, 5 per cent. are micrococcus pyogenes aurens, 2 per cent. micrococcus pyogenes albus, and the remainder (38 per cent.) are nitrifying bacteria, both identified and unidentified.

"The dark color seems in all probability to be due to oxidizable organic matter, as it is immediately dispelled by an oxidizing agent, even exposure to air accomplishing this effect." (Signed) W. M. S. Coplin and H. F. Harris.

Some of the best known bacteriologists and chemists I herewith quote as a proof of the purifying agents of light, air and of the action of hardy nitrifying bacteria.

Dr. Palermo, Naples, Italy, says: "Sunlight is a microbe-killer, especially those that are noxious to human or animal life."

M. Marshall Ward, Percy F. Frankland, Mr. Buchner and Mr. Kotljar have proven by demonstration that water is

purified by light. Moreover, the experiments prove that the bacteria spores are really killed and not merely retarded in development. These specialists state generally that there is one natural agency, at least, which destroys anthrax spores in surface water, viz., the action of direct sunshine.

M. P. Leonard says: "Water falling in drops upon water or wet bodies generates electricity, the water becoming positively electrified. The essential conditions of electrification are the concussions among the drops themselves and against the wet rock, etc."

Professor Esmarch says "that sunshine is the best of all disinfectants and disease germ destroyers."

Professor Koch and Professor Pasteur, of Paris, since their early investigations, have maintained and confirmed similar conclusions.

Dr. Dupree, of London, England, says: "The aerobian and atmospheric forms of life could be caused to grow particularly near the surface. If the sewage were well aërated before, during and after treatment, it would be certain that the microbe life would assume that form which produced the least objectionable by-products. Aerobic bacteria effect complete decomposition of the organic matter in water or sewage, which is nitrification, or a conversion of organic and inorganic matter into nitrates and nitrites."

Mr. Geo. W. Fuller, biologist, late in charge of experiment station at Lawrence, says: "that only the non-pathogenic bacteria find their way through the filters, and the germs of disease early succumb to the unfavorable conditions found in the sand bed. The few bacteria found in the effluent belong to the hardy species of water bacteria, many of which exist in spores. The evidence now at hand shows that the disease-producing bacteria are among the first to succumb, because farthest removed from their natural habitat."

The noted German experts on analyses of water, Fraenkel and Piefke, assert that "every surface water before it is used for drinking purposes should be freed from all infectious substances. For this purpose, whenever large quantities of water are to be treated, sand filtration is at present the most convenient and effective method."

Prof. Thos. M. Drown, President Lehigh University, says: "In the first quarter of an inch of a filter bed, the bacteria are present by the million, and that the number rapidly decreases as depth increases, and that at the depth of a foot there are very few within it. The work of a filter is mainly done in the upper 3 or 4 inches."

In the autumn of 1894, a number of papers were read by sanitary experts as a result of their experiments before the Société de Biologie, and shortly thereafter at the International Congress of Medical Societies, at Rome, Italy. The following are quotations from them:

"Cold acts quite promptly on microbes, checking their development and secretions; but, in order to destroy them, we have to go down to extremely low temperatures; even at 60° below melting ice refrigeration has to be continued for a number of hours in order to annihilate micro-organisms. These results enable us to understand why, in contradiction to what is usually believed, epidemics break out in spite of rigorous winter weather.

"Heat is more effective; and yet to sterilize completely —that is to say, to kill all germs and their spores, and render their secretions harmless—it is necessary to reach or exceed a temperature of 200° C.

"Of all the physical agents that surround us *light* is, from a practical point of view, the most interesting and perhaps the most important as regards the present subject. With the other agents—pressure, cold, heat, etc.—in order to kill microbes by their action, we are obliged to apply them under abnormal circumstances. But *light*, as it exists about us, is very energetic, and its effect manifests itself whether it comes from the sun or from an electric arc."

Dr. Park, of New York, says: "The ruling entity of zymotic or germ sickness is the microbe lurking in all dark, mouldy and unclean places. Its quickest destroyer is the sunbeam, aided by currents of fresh, pure air."

In experiments by Professor Buchner, he says: "Cultures of typhoid and other bacilli placed in water were completely destroyed in three hours by bright sunlight, and rapidly reduced even by diffuse daylight, although they

rapidly increased in the dark. To determine the depth at which this bacteriological action of light ceases, partially exposed cultures of different bacteria were sunk in Stamberger Lake, near Munich. At three yards below the surface the retarding effect was only just perceptible, although it was shown, ten years ago, that light penetrates in water—at least in the Lake of Geneva—to depths as great as 185 yards. It is apparent, therefore, that the effect of sunlight in purifying rivers has been overestimated, and is confined to the surface."

The conclusion and recommendation of experts recited, as well as that of my own experience and investigations, cause me to announce that they may be all embodied in a plant to purify the entire water supply of the city of Philadelphia. With that object in view, all data pertaining to the subject has been secured and drawings have been made to incorporate substantially all the best features of the suspended screening chamber, and the filtration beds as installed and in operation at Reading, Pa. The screening chambers can be placed at the intakes or at the filter beds receiving the water from the pumping mains. The latter is more preferable than the first. The water from the pumping mains would be received into a series of distributors, as shown by the illustration. These distributors would receive the benefits of light and air. The water would pass over the edges in thin films, and thence over a series of splash plates, when the water would reach the upper grating of the suspended screening floors, in an aërated condition.

The suspended screening floors would consist of layers of breeze coke, 12 inches deep, supported on a lower grating, with wire netting over the same, while the upper grating would serve the purpose of holding the breeze coke in place and to prevent floating. It would be arranged in sections for removal. The water in its transit would be distributed over the entire area of the suspended coke beds. The water would percolate through the coke beds, and drop from the lower grating onto a collecting floor, which would serve the purpose as the supply chamber to the mains and distributors

of the filter beds. The coke in the screening chambers will absorb large floating matter as well as considerable of the largest matter in suspension. At the same time it will remove from 25 to 30 per cent. of all bacteria. The suspended screens will be supplied with a liberal circulation of air both above and below. After running for a couple of weeks, the upper gratings would be removed, as well as all matter adhering to it, and about 4 inches in depth of coke breeze, this material, of course, serving the purpose of fuel for the pumping stations that are established in the high level distribution, and the remainder could be sold and removed as fuel. The water on the collecting floor, which has been partially purified, will then flow by gravity to the mains supplying the various compartments of the filter. The filters will be constructed of iron or masonry or combination of embedded steel and concrete. They will be divided into 1,000,000 gallon compartments, and will be elevated above the ground, as shown by the illustration, with the addition of a roof and sides. The water will pass through the laterals and distributors. The water will be exposed to the light from abundant skylights, and, as it flows over the edges in a thin film, it will be thoroughly aërated. In its descent it will strike on splash-plates or screening slats, which will separate the liquid into small particles. The composition of the beds in all particulars will be the same as those at Reading. The structure, where placed in the Park adjacent to the reservoir, can be treated architecturally in a way to satisfy the lover of the æsthetic as well as of the practical, since due consideration will be given to the site chosen. It is possible in some places to provide shelters or pavilions for the use of the people in combination with the filters.

The water, on reaching the surface of the filter bed, will make the usual deposit and form the gelatinous surface over the sand which is formed in combination by the action of the hardy scavenger bacteria within the bed as well as the matter in suspension which is deposited thereon. It will be readily seen that the air penetrates the beds to their full thickness, since the air is in circulation both below and

above the bed. The healthy micro-organisms therein established are enabled by this means to perform their functions in bringing about a conversion of all organic and inorganic matter into harmless mineral products. There is no pressure of water above the surface other than depth contained, which would be about a foot. There will be no wasting of water, since washing will at no time be necessary for the filter, nor are chemicals used at any time during the process of purification of the water. The water, in trickling in small globules like rain from the under surface of the filter beds, descends through the atmosphere for 10 feet before it reaches the collecting floor and pipes, from whence it flows into the reservoir. By this means the water which has been sterilized is revitalized so as to make it sparkling and palatable. At the same time, should there be any pathogenic bacteria within the globules, they would be oxidized or burnt up in the presence of the oxygen in the air, while all gases in solution that would be in the water during the process of purification would be set free in the atmosphere.

The reservoirs of the city would be converted into and used as clear-water basins. All sediment, fish and other offensive matter would be by this process excluded from the reservoir. The water discharged from filters would be chemically and bacterially pure to an extent of at least 98 per cent. The other 2 per cent. soon die, since their nourishment has been removed in the process of purification. About every two to four weeks a compartment would be put out of use for cleansing purposes; the deposit formed on the surface, together with the sand that adheres to it, usually $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, would readily dry and would be removed. It is possible to clean the sand by washing it, but more preferably by baking it in a revolving furnace, when it would be transferred to a fan or blower, so that the fine soot would be blown off and the sand discharged into bins, where it would be re-used on the surface of the filter beds as a substitute for that taken off previously. By this arrangement large piles or dumps would not be a product of the operation, and at the same time it would be economical in the operation and maintenance of the plant.

It is possible to construct these filter beds either within the reservoir or on suitable land adjacent to them. The city possesses 191·4 acres of basins at the water level. The area is more than double that required for the installation of these filter beds, while the embankment and land immediately adjacent are also sufficient in every instance to provide the filter beds, of adequate capacity to purify the water that is daily pumped or discharged into them.

The area required for the sand filtration process as established at Lawrence, Hamburg and London is 70 gallons per square foot of the surface. Our standard would be 280 gallons per square foot of surface, and for the suspended screening coke beds would be 3,000 gallons per square foot of surface. The water plant at Wilmington, Del., is on the basis of 1,000 gallons per square foot of surface. The chemical and pressure processes are from 3,000 to 4,000 gallons per square foot of surface.

I recite these areas in order to convey to your minds that the process proposed by the company for the city of Philadelphia is slow sand filtration by gravity, and that it has features containing the recommendation of the best experts and scientists of the world, which are notably absent in the plants at Lawrence, Hamburg and London.

These plants can be constructed for the entire water supply of Philadelphia at Belmont, Roxborough, East Park, Queen Lane and Wentz Farm, of a total capacity of 300,000,000 gallons per day, and would be in readiness for operation in less than twelve months; that is to say, complete in every particular, furnishing every water outlet in each person's residence or building with clear, bright, sparkling, odorless water, free from all disease germs, and chemically and bacterially pure to an extent of from 98 to 99 per cent.

That date would mark an epoch in the history of Philadelphia, for, practically, epidemics of typhoid fever and kindred diseases would become past history, and the comfort and happiness and health of the inhabitants would be increased, so that the city of Philadelphia would become the most healthful city in the world.

THE EFFECT OF SALT WATER ON CEMENT.

BY A. S. COOPER.

The present article, while not pretending to go as thoroughly into this subject as others have done, will give the results of some experiments, which will go far towards settling a few points in this much-disputed question. In cold climates it is a general custom to put salt in the gauging water to prevent the mortar from freezing before it is placed in the works; and on the sea-coast it is often customary to gauge cement mortar with sea water rather than go to any extra expense to obtain fresh. The experiments given in this article were designed to determine whether or not this is good practice, and also to ascertain the effect of sea water on concrete structures. It was the intention to have them extend over a period of several years, but as circumstances interfered with the long-time tests, they were discontinued at the end of one year. They are, therefore, of very little value as showing the effect of sea water on engineering structures, but show conclusively the ill-effect of salt in gauging mortar.

DESCRIPTION OF TESTS.

Briquettes were made in moulds of the form recommended by the American Society of Civil Engineers in 1885, and the mortar rammed into them by a German hammer machine, striking 120 blows on each briquette, using about a 3-pound hammer and a 10-inch drop. The mortar was made as near a standard consistency as possible, water being added until it just appeared below the moulds, when the hammering ceased. All briquettes of like mixtures were gauged with the same per cent. of water. The mixing was done with a Riehlé mixing machine, using about 100 turns. Proportions were determined by carefully weighing each batch. The briquettes were stored in moist air for twenty-four hours and then placed in the immersion tanks, where they remained until broken. No at-

References to Diagrams.

———— Indicates briquettes mixed with fresh water and immersed in fresh water.
— — — — — " " " " fresh " " " " salt "
— — · — — " " " " salt " " " " salt "
· · · · · · · · · · " " " " salt " " " " fresh "

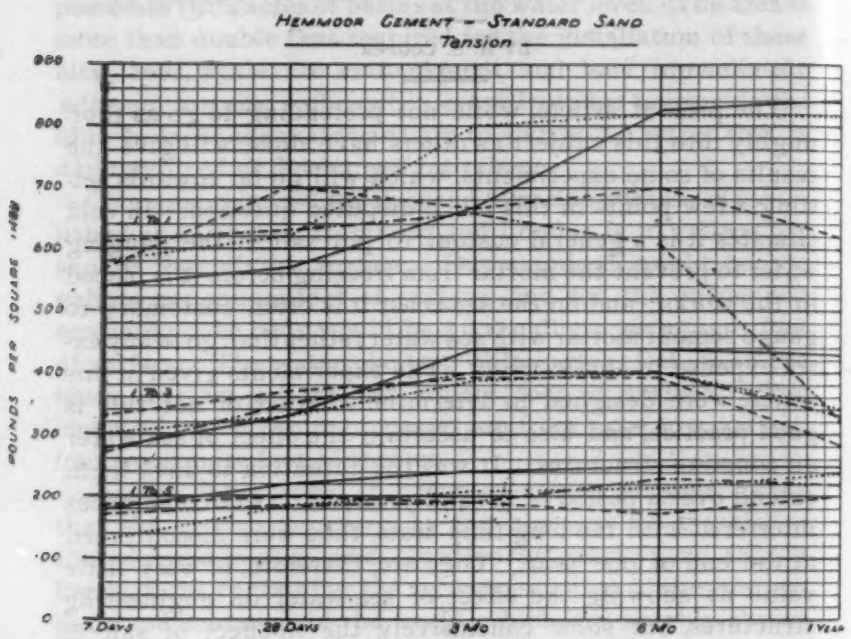


Diagram No. 1.

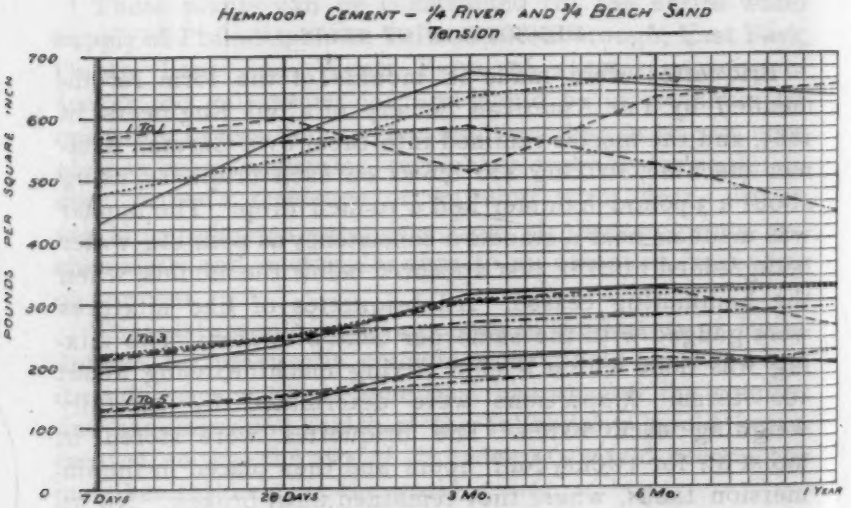


Diagram No. 2.

tempt was made to keep the tanks at a uniform temperature, but as the briquettes which were to be compared with each other were all made practically at the same time, the comparisons are still accurate without this precaution. The fresh water tank was renewed as often as the water became noticeably alkaline. The salt water tank was filled with sea water and only changed three times, but as the

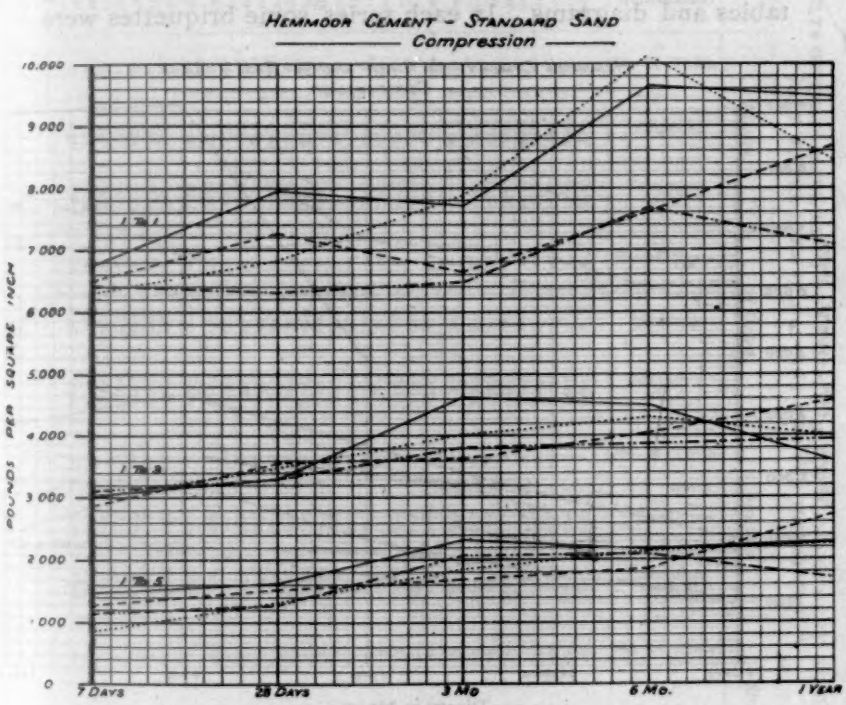


Diagram No. 3.

volume of water was fully 100 times the volume of the briquettes stored, it was not thought necessary to renew the water oftener. The briquettes were first broken on a Fairbanks tension machine, and then a heavy rubber band put on them to hold the two parts together, and crushed on a Riehlé machine, worked with hydraulic pressure. Series of tests were made with two brands of cement, one a natural and the other a Portland. In each case all of the ce-

ment came out of the same barrel. Sets were made with standard sand, and also with natural sand found in this vicinity. In the case of the natural cement, mortar was mixed in the proportion of 1 to 1, 1 to 2 and 1 to 3; and with the Portland, 1 to 1, 1 to 2, 1 to 3 and 1 to 5. A sufficient number of sets of each were made with fresh water and with salt, and each immersed in fresh and salt water to complete all of the different series given in the accompanying tables and diagrams. In each series some briquettes were

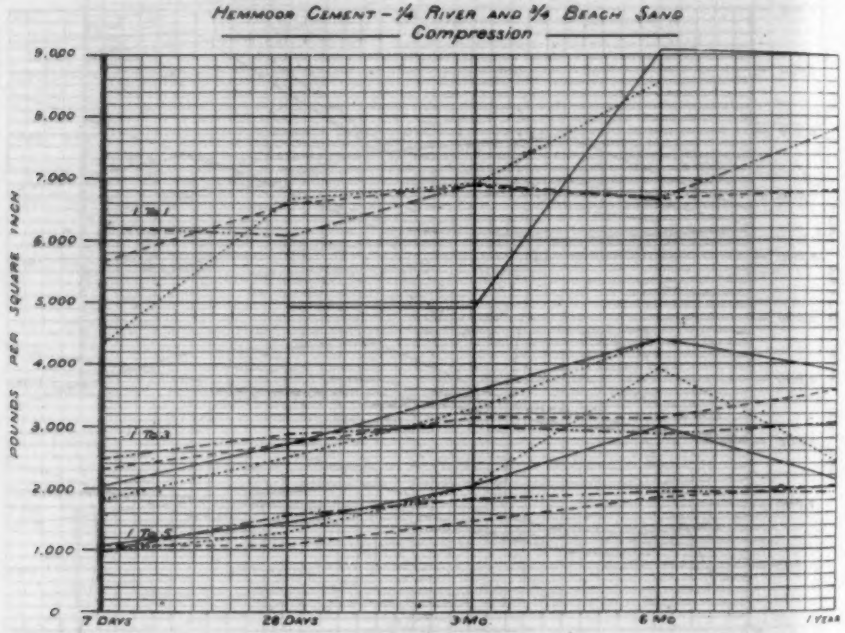


Diagram No. 4.

broken at 7 days, 28 days, 3 months, 6 months and 1 year. It was the intention to break some at the end of 3 years and 5 years, but this part of the experiments had to be abandoned. In the tables and diagrams, all strains are given in pounds per square inch of section or surface.

RESULTS OF TESTS.

By a reference to Table No. 1 and Diagrams Nos. 1 to 4, it will be seen that in case of the Portland cement the bri-

TABLE No. 1.—SHOWING RESULTS OF TESTS MADE FROM ONE SAMPLE OF PORTLAND CEMENT, TO DETERMINE THE EFFECT OF SALT WATER USED IN GAUGING AND FOR IMMERSION.

Sand.		Water.			7 Days.			28 Days.			3 Months.			6 Months.			1 Year.		
Kind.	Ratio to 1 of Cement.	Per Cent. to Dry Ingredients.	Gauging.	Immersion.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.
Standard	1	8·9	Fresh	Fresh	2	544	6779	2	574	7980	2	671	7734	2	833	9658	2	846	9485
"	1	8·7	Salt	"	2	585	6340	2	621	6808	2	801	7830	2	820	10188	2	819	8465
"	2	6·7	Fresh	"	2	487	6484	2	560	7200	2	584	6332	2	627	7580	2	587	7660
"	2	7·8	Salt	"	2	458	5666	2	507	5876	2	580	7175	2	630	7362	2	614	6850
"	3	7·8	Fresh	"	2	278	3938	2	335	3315	2	438	4602	2	444	4480	2	431	3594
"	3	7·8	Salt	"	2	303	3666	2	330	3587	2	391	4025	2	408	4325	2	344	4020
"	5	7·2	Fresh	"	2	182	1478	2	221	1666	2	242	2354	2	251	2692	2	252	2250
"	5	7·3	Salt	"	2	135	982	2	183	1368	2	219	1850	2	216	2188	2	243	2288
¼ River ¾ Beach	1	10·0	Fresh	"	2	434	—	2	571	4981	2	674	4932	2	657	9131	2	636	9040
"	1	10·1	Salt	"	2	479	4378	2	535	6679	2	537	6875	2	662	8518	—	—	—
"	2	9·3	Fresh	"	2	285	3475	2	350	4175	2	413	4775	2	447	7175	2	505	7134
"	2	9·7	Salt	"	2	339	4025	2	405	4017	2	439	5425	2	459	6194	2	487	5630
"	3	9·3	Fresh	"	2	193	2012	2	236	2736	2	317	3570	2	312	4395	2	324	3880
"	3	9·4	Salt	"	2	210	1812	2	260	2500	2	304	3350	2	323	4400	2	326	3930
"	5	9·3	Fresh	"	2	120	1100	2	135	1468	2	211	1970	2	222	3200	2	198	2140
"	5	9·4	Salt	"	2	136	1000	2	155	1294	2	194	2025	2	199	3965	4	208	2396
Standard	1	9·4	Fresh	Salt	2	568	6502	2	709	7256	2	670	6640	2	708	7655	2	625	8706
"	1	8·7	Salt	"	2	618	6436	2	631	6325	2	660	6462	2	610	7700	2	318	7107
"	2	7·3	Fresh	"	2	477	5419	2	586	6590	2	600	5678	2	637	7461	2	471	7171
"	2	7·7	Salt	"	2	492	5750	2	554	6357	2	583	7606	2	589	7605	2	478	5900
"	3	7·3	Fresh	"	2	329	3928	2	376	3600	2	392	3631	2	397	4040	2	282	4584
"	3	7·3	Salt	"	2	270	3157	2	348	3280	2	400	3732	2	408	3872	2	335	3956
"	5	6·8	Fresh	"	2	184	1290	2	199	1548	—	—	—	2	176	1900	2	205	2725
"	5	6·8	Salt	"	2	173	1190	2	193	1256	2	196	2062	2	231	2125	2	220	1744
¼ River ¾ Beach	1	9·6	Fresh	"	2	570	5644	2	599	6607	2	517	6942	2	634	6700	2	655	6850
"	1	9·6	Salt	"	2	549	6218	2	563	6062	2	586	6841	2	526	6700	2	445	7875
"	2	9·6	Fresh	"	2	336	3870	2	373	4276	2	417	4595	2	411	5787	2	380	5160
"	2	9·1	Salt	"	2	305	3782	2	352	4075	2	370	3780	2	400	4830	2	362	5912
"	3	9·1	Fresh	"	2	216	2375	2	262	2697	2	273	3190	2	309	3125	2	261	3607
"	3	8·8	Salt	"	2	218	2453	2	248	2966	2	269	3025	2	277	2875	2	292	3060
"	5	9·1	Fresh	"	2	137	1124	2	151	1100	2	188	1540	2	213	1916	2	200	2070
"	5	8·8	Salt	"	2	131	989	2	150	1594	2	177	1816	2	196	1964	2	221	1935

quettes mixed with salt water were ahead of those mixed with fresh on short-time tests, but that the long-time tests nearly always showed the superior strength of the briquettes mixed with fresh water, and this was just as pronounced in the compression as in the tension tests. It will also be noticed that the deteriorating effect of salt water in gauging is the greatest on the richer mortars. The test

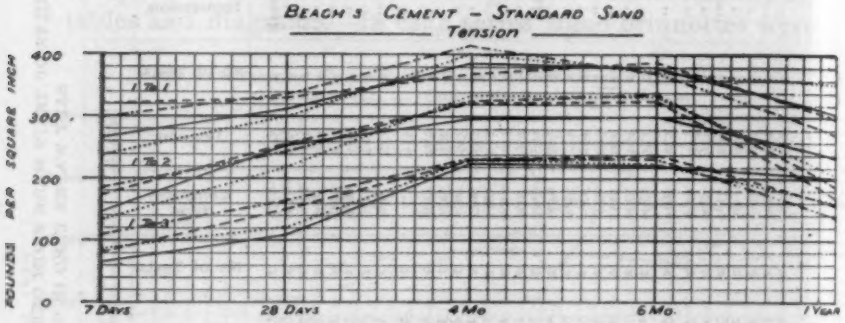


Diagram No. 5.

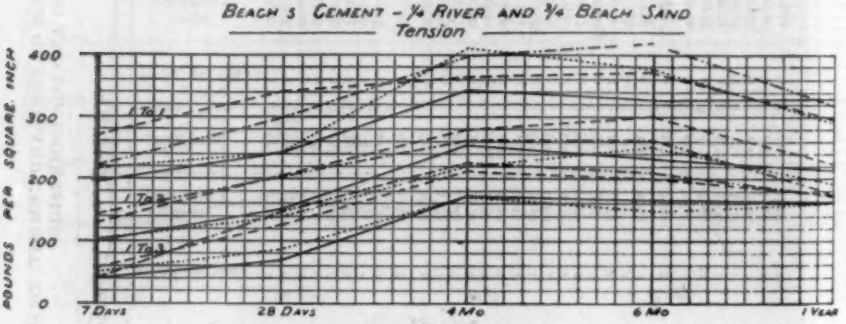


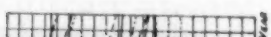
Diagram No. 6.

pieces that were immersed in salt water nearly always fell below the corresponding ones that were placed in fresh.

In a general way the same thing will be noticed in the case of the natural cement tests, Table No. 2 and Diagrams Nos. 5 to 8. The sample selected, however, seems to have been a poor one, as it shows less strength at one year's time than at six months. The decrease of the salt water briquettes is greater than the fresh, and therefore shows the

TABLE No. 2.—SHOWING RESULTS OF TESTS MADE FROM ONE SAMPLE OF NATURAL CEMENT TO DETERMINE THE EFFECT OF SALT WATER USED IN GAUGING AND FOR IMMERSION.

Sand.		Water.			7 Days.			28 Days.			4 Months.			6 Months.			1 Year.		
Kind.	Ratio to 1 of Cement.	Per Cent. to Dry Ingredients.	Gauging.	Immersion.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension.	Compression.	No. of Tests.	Tension	Compression.
Standard	1	11·1	Fresh	Fresh	1	266	2586	2	310	3577	2	385	4506	2	377	—	2	305	5505
"	1	11·1	Salt	"	2	237	3106	2	297	3910	2	400	4789	2	370	—	2	356	5460
"	2	9·3	Fresh	"	2	147	2223	2	250	2685	2	296	3712	2	298	—	2	235	4266
"	2	9·3	Salt	"	2	134	2105	2	218	2558	2	335	3519	2	332	—	2	207	4039
"	3	9·3	Fresh	"	2	65	1020	2	107	1887	2	223	2572	2	221	—	2	200	3236
"	3	9·3	Salt	"	2	87	—	2	120	1410	2	230	1901	2	238	—	2	173	2056
¼ River ¾ Beach	1	12·0	Fresh	"	1	198	2412	2	241	3261	2	342	3987	2	327	—	2	328	4036
"	1	12·0	Salt	"	2	217	2555	2	242	3380	2	409	4068	2	378	—	2	291	3405
"	2	10·9	Fresh	"	2	101	1346	2	148	1800	2	257	3112	2	232	—	2	210	4049
"	2	10·3	Salt	"	2	143	1047	2	201	1658	2	269	2138	2	263	—	2	175	2092
"	3	10·4	Fresh	"	2	41	—	2	68	1002	2	174	1619	2	166	—	2	162	2675
"	3	10·4	Salt	"	2	55	—	2	88	—	2	172	1535	1	150	—	2	160	1987
Standard	1	11·1	Fresh	Salt	2	320	3212	2	331	3634	2	369	3720	2	388	—	2	299	3525
"	1	11·1	Salt	"	2	298	3042	2	334	3750	2	414	3687	2	368	3212	4	275	3315
"	2	9·6	Fresh	"	2	177	2240	2	256	2317	2	322	2921	2	325	—	2	170	2939
"	2	10·4	Salt	"	2	188	2532	2	243	2700	2	325	2959	2	334	3112	2	191	2581
"	3	9·3	Fresh	"	2	92	1084	2	150	1440	2	228	1440	2	223	—	2	162	1940
"	3	9·3	Salt	"	2	110	1218	2	164	1455	2	232	1650	2	237	—	2	140	1804
¼ River ¾ Beach	1	11·8	Fresh	"	2	274	2691	2	341	3052	2	365	2700	2	376	4187	2	294	2701
"	1	12·0	Salt	"	2	223	2687	2	297	3068	2	397	2871	2	419	—	2	318	3270
"	2	10·4	Fresh	"	2	131	1312	2	207	1880	2	281	2268	2	301	2540	2	231	2617
"	2	10·5	Salt	"	2	143	1047	2	201	1658	2	260	2138	2	263	—	2	175	2093
"	3	10·1	Fresh	"	2	58	581	2	125	1061	2	210	1460	2	200	1834	2	187	1770
"	3	10·4	Salt	"	1	40	—	2	149	920	2	227	1552	2	216	—	2	175	1819



same results as in the other case. In the compression tests with this sample the results are better.

CONCLUSIONS.

These results would seem to justify the conclusion that salt water is injurious to cement mortar, and that the use of

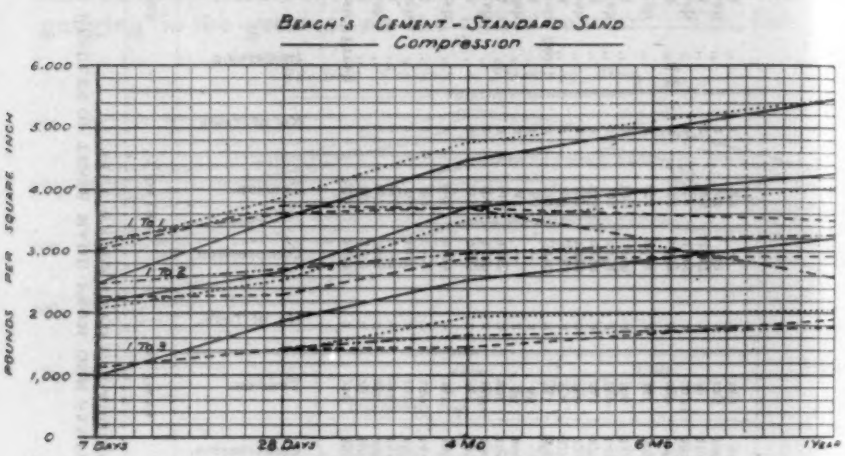


Diagram No. 7.

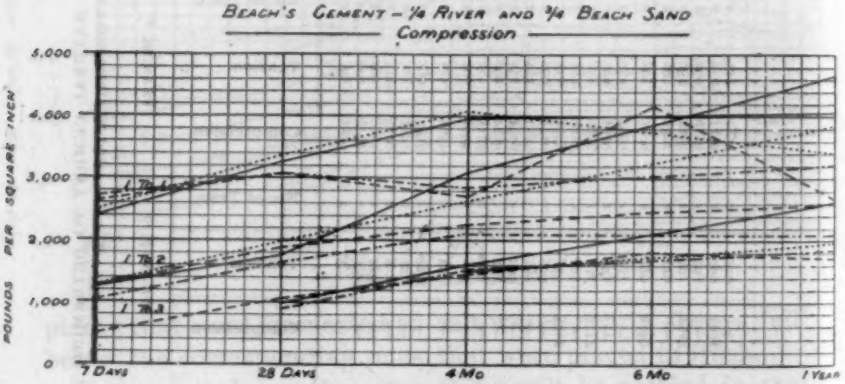


Diagram No. 8.

salt or sea water in gauging mortar is bad practice. The tests are not extended over a sufficient length of time to draw a decided conclusion as to the effect of sea water on engineering structures built of concrete, gauged with fresh

water, but they seem to point to a tendency to weaken them.

TABLE No. 3.—BRIQUETTES MADE OF ONE SAMPLE OF PORTLAND CEMENT AND BROKEN AT 11 MONTHS, TO TEST THE EFFECT OF SIZE OF SAND WHEN PERFECTLY RAMMED INTO MOULDS.

GRANITE SAND.

Sand.		Water, Per Cent. of.	Tension.				Compression.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.	No. of Tests.	Highest.	Lowest.	Mean.
6–8	3	7·3	3	418	314	381	3	5325	4350	4675
8–12	3	7·3	4	392	314	359	4	4225	3520	3918
12–16	3	7·3	4	320	280	300	3	3300	2800	3100
16–20	3	7·7	4	412	316	350	4	3833	3312	3503
20–30	3	7·7	4	428	357	386	3	3200	2380	2833
30–100	3	8·3	4	371	282	340	2	3080	2725	2902
Passed 100	3	8·3	4	315	270	290	3	3400	3212	3333
6–8	1	8·3	4	544	460	493	4	7600	5975	7012
8–12	1	8·3	3	554	482	513	3	7825	6500	7041
12–16	1	8·3	4	610	540	571	4	7725	6612	7194
16–20	1	8·3	4	622	572	597	4	8075	6700	7240
20–30	1	8·8	4	680	584	618	4	7925	7425	7781
30–100	1	9·3	4	675	643	660	3	8175	7837	7903
Passed 100	1	9·9	4	535	498	518	4	6088	5825	5956

TABLE No. 4.—QUARTZ SAND.

Sand.		Water, Per Cent. of.	Tension.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.
12–16	3	7·3	4	471	351	405
16–20	3	7·3	4	453	375	413
20–30	3	7·8	4	386	333	356
20–30	1	8·8	4	815	745	781

EFFECT OF SIZE OF SAND ON CEMENT MORTAR.

In the September number of the *Journal of the Franklin Institute*, 1896, was published an article on the effect

TABLE No. 5.—TRAP ROCK.

Sand.		Water, Per Cent. of.	Tension.				Compression.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.	No. of Tests.	Highest.	Lowest.	Mean.
6–8	3	6·3	4	407	396	402	3	5025	4200	4700
8–12	3	6·3	4	461	261	349	4	4975	2750	3862
12–16	3	6·8	4	455	337	401	4	5375	3750	4494
20–30	3	6·8	4	407	290	369	4	4425	3025	3787
30–100	3	7·3	4	415	333	378	4	4500	3175	3725
Passed 100	3	8·3	4	365	282	321	4	4550	3575	4081
8–12	1	7·3	4	692	555	600	4	8325	6250	7106
12–16	1	7·3	4	730	565	621	4	8825	7675	8381
16–20	1	7·8	4	775	650	714	4	9500	8050	8962
20–30	1	8·0	2	671	632	651	2	10025	9775	9900
30–100	1	8·9	4	820	630	723	4	9725	7325	8675
Passed 100	1	13·0	4	837	640	747	4	8450	7800	8162

TABLE No. 6.—RIVER SAND.

Sand.		Water, Per Cent. of.	Tension.				Compression.			
Size.	Ratio to 1 of Cement.		No. of Tests.	Highest.	Lowest.	Mean.	No. of Tests.	Highest.	Lowest.	Mean.
6–8	3	6·3	4	393	257	318	4	5750	4050	4718
8–12	3	6·3	4	372	300	331	4	5575	5075	5331
12–16	3	6·3	4	327	234	282	4	5025	4350	4712
16–20	3	6·7	4	385	239	314	3	4400	3675	4125
20–30	3	7·3	4	373	279	313	4	5500	4350	4772
6–8	1	7·3	4	446	350	397	4	6800	5750	6387
8–12	1	8·3	4	494	437	476	4	8100	6950	7562
12–16	1	8·3	4	592	577	587	4	8750	6875	8106
16–20	1	8·3	4	705	564	615	4	8800	8325	8460
20–30	1	8·3	4	660	625	635	4	9137	7975	8846

TABLE No. 7.—TEST OF BRIQUETTES MADE OF ONE SAMPLE OF PORTLAND CEMENT, PROPORTION 1 : 3, AND BROKEN AFTER ONE YEAR'S TIME, TO DETERMINE THE EFFECT OF LETTING MORTAR STAND AFTER MIXING.

Kind of Sand.	Per Cent. of Water.	Made When Mixed.		Made 1 Hour After Mixing.		Made 2 Hours After Mixing.		Made 3 Hours After Mixing.		Made 4 Hours After Mixing.		Made 5 Hours After Mixing.		Made 6 Hours After Mixing.		Made 7 Hours After Mixing.		Made 8½ Hours After Mixing.	
		Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.	Tension.	Compression.
Beach.	14·	232	2350	248	2400	227	2487	211	2440	—	—	—	—	—	—	—	—	—	—
"	9·7	182	2056	181	1700	172	1553	176	1650	—	—	—	—	—	—	—	—	—	—
"	15·3	240	2400	230	2185	245	2523	227	2270	—	—	229	2306	—	—	226	2281	236	2260
River.	13·9	244	2775	233	2794	194	3031	—	—	240	2987	—	—	259	2715	235	2756	—	—

of the size of sand, in which it was clearly shown that coarse sand made the strongest mortar. In Tables Nos. 3 to 6 will be found another series of tests on the same subject, but in this case the briquettes were all made on a hammer machine after the method just described.

From these tests it will be seen that when perfectly rammed the size of the sand is not so important as with ordinary ramming. It is evident, however, that the size of the sand has some effect even with these briquettes, and the richer the mortar the less the effect of the size of the sand becomes. The large sand also shows to better effect in the compression tests than in the tension.

The superior strength of the rougher sands, like that obtained from breaking up trap rock, is, however, just as apparent with these perfectly rammed briquettes as it was with those made in the ordinary way. It would, therefore, be a safe conclusion that the condition of the surface of any sand is a more important factor in the strength of concrete than the size.

TIME OF SET.

As it is the prevailing opinion with many engineers that a cement mortar which has stood an hour or two has lost some of its strength, it is thought worth while to give here a set of tests made to determine the amount of lost strength of Portland cement mortar due to its standing after mixing and before using. Four large batches of mortar were mixed and briquettes made by hand from each pile at intervals ranging up to eight and one-half hours after mixing. These were all carefully marked and stored away as usual, and broken after one year. The results are shown in Table No. 7, from which it will be seen that the loss of strength after eight and one-half hours' standing is practically nothing.

In practical working with most Portland cement, if it becomes necessary for the mortar to stand for one-half of a day even, no injury will result, provided the precaution is taken to keep the mortar wet.

U. S. ENGINEER'S OFFICE,
SAVANNAH, GA., January 8, 1899.

ON GASEOUS MIXTURES.

Two notes translated by B. F. Isherwood, U. S. Navy, from the *Comptes Rendus de l'Académie* of 1898, pages 218 and 338. The first note is by A. Leduc; the second note is by Paul Sacerdote.

FIRST NOTE. (BY LEDUC.)

Natural gases are too often likened to perfect gases. Thus, the law of gaseous mixtures is always stated in the following terms, which are in contradiction of the result of Berthollet's experiment* that they are supposed to express.

"*The pressure of a mixture of gases is equal to the sum of the pressures that each would have if it alone occupied the receptacle at the same temperature.*"

A priori, this law has but little probability. Referring to Berthollet's experiment of putting carbonic acid gas in the two receptacles, clearly their interdiffusion cannot produce the least change of pressure.

Let the CO_2 in one of these receptacles be replaced with Az_2O, which has sensibly the same critical constants, the same molecular mass and the same atomicity.

That the intermixture of the molecules of these two gases, physically identical apparently, will produce a variation of pressure cannot be conceived; nevertheless, the law above quoted predicts an increase of pressure of 2·6 millimeters. An experiment quickly shows that no such increase is produced.

I propose, therefore, to substitute for this law, which is always in default, the following law, which is rigorously exact in some cases and very closely approximate in general:

The volume occupied by a mixture of gases is equal to the sum of the volumes that would be occupied by the gases which compose it under the pressure and at the temperature of the mixture.

* There results from both Regnault's experiments and my own that, if the law in question be exact, Berthollet should have confessed he had found an increase of pressure of 1·1 millimeters. I willingly admit that this increase had escaped his observation, but in that case he ought to have formulated the law *notwithstanding* instead of *because* of his experiment.

A long time ago investigations of the composition of atmospheric air led me to an equivalent announcement.

In a gaseous mixture each gas should be considered as under the total pressure, and not under the pressure it would have if it alone occupied the recipient.

(1) *Atmospheric Air.*—Thus, if the proportion of oxygen (x in volume) contained in air deprived of aqueous vapor, carbonic acid, etc., be sought by means of the densities of oxygen and of atmospheric nitrogen, there should be written

$$x \times 1{\cdot}10523 + (1 - x)\, 0{\cdot}97203 = 1,$$

which gives $x = 0{\cdot}21$ sensibly, and the proportion of oxygen in weight 0·2321, which latter I have found directly by experiment.

If, on the contrary, y be called the fraction of the total pressure due to the oxygen, there should be written, according to the classic law,

$$y \times 1{\cdot}10457 + (1 - y)\, 0{\cdot}97195 = 1,$$

whence $y = 0{\cdot}212$, and the proportion in weight $= 0{\cdot}2333$.

These results, together with those of my own experiments, as well as those obtained by Mr. Schloesing, Jr., show inadmissible discrepancies.

Although this single case is sufficient to warrant the rejection of the law in question, I have deemed that several other particular cases should also be submitted to experiment.

(2) *Protoxide of Nitrogen and Carbonic Acid Gas.*—Into my specific gravity receptacle I first introduced some protoxide of nitrogen at 0° under the pressure P, near 33 centimeters, and ascertained its weight. Then I added some pure carbonic acid gas under the pressure P_2, near 66 centimeters, and ascertained the increase of weight p.

Let V be the volume of the receptacle. Knowing the compressibility of the two gases, and the normal density of the second gas, I calculated the volume V' to which the Az_2O is reduced under the pressure P_2; then I calculated the weight p' of CO_2, which completes the filling of the receptacle ($V - V'$) under the pressure P_2.

The difference found ($p - p' = 1{\cdot}3$ milligrams) is imputable to the different errors accumulated; it corresponds to a diminution of pressure of 0·2 millimeter, while the classic law requires an augmentation of 2·3 millimeters.

(3) *Carbonic and Sulphurous Anhydrides.*—The same operations and the same calculations being made, I have found experimentally

$$p = 3{\cdot}0411 \text{ grams, and } p' = 3{\cdot}0520 \text{ grams.}$$

If the law that I propose were not complicated by secondary phenomena, there could then enter into my receptacle 10·0 milligrams more of sulphurous gas.

I express this fact by saying that the gaseous mixture has been accompanied by an augmentation of pressure of 1·25 milligrams. The classic law requires an augmentation four times as great.

This augmentation of pressure can be attributed to the very different molecular weights of the mixed gases, these gases being far from being in corresponding states. Be that as it may, there can be no doubt of the experimental results.*

Application.—I have calculated anteriorly † the density of argon by employing my law of volumes—a method previously justified by the case of air—and by employing my densities of chemical nitrogen and of atmospheric nitrogen, as well as the proportion of *argon* in the latter according to Mr. Schloesing. I have found 19·80 instead of 19·94 found by Lord Rayleigh and Mr. Ramsay.

The difference is caused, in all probability, by the augmentation of pressure (or of volume) which ensues on the mixing of the nitrogen with the argon, similar to the case of SO_2 and CO_2; 10,000 volumes of atmospheric nitrogen are formed of 9,880 volumes of nitrogen and 119 volumes of argon. The molecules of the argon differ from those of the

* Mr. Sacerdote, who has very obligingly aided me in the making of these experiments, will repeat, with the greatest care, the experiment of Berthollet, which has the advantage of being direct, and his results will form the subject of a communication in the near future.

† *Comptes Rendus*, Vol. CXXIII, Page 805. 1896.

nitrogen not only by their mass, but also by their atomicity.

SECOND NOTE. (BY SACERDOTE.)

In a recent communication* Mr. Leduc has shown that the law of the mixture of gases, applied by means of the coëfficients of difference from the law of Mariotte, which we have precedingly measured,† leads to the following result:

Two gases under the same pressure being mixed, will, in consequence of that mixture, have an increase of pressure. For CO_2 and SO_2, primitively at the pressure of 76 centimeters of mercury, the increase of pressure should be more than 0·5 centimeter of mercury. This has been verified by an indirect method based on measurement by densities, but such a method is not sufficient for demonstrating the necessity of a new law of gaseous mixtures.

These experiments made by measurement by densities are capable of very great precision, but they require multiple conditions, among others a nearly absolute purity of the gases; further, they have the inconvenience of making the verification sought depend on a certain number of numerical constants for the gases.

Direct experiments seemed then to be necessary for solving the problem; and, with the aid of the kindly counsels of Mr. Leduc, I proposed to repeat the experiment of Berthollet, but making it with all the precision obtainable by our actual methods of measurement.

Apparatus.—Two glass receptacles, of 750 cubic centimeters each, are connected by a three-way cock of 6 millimeters diameter, so as to permit a rapid diffusion of the gases. The necks bend at a right angle, in order that they can, after the filling of one of the receptacles, isolate it completely. The apparatus was perfectly dried by heating it for several hours, during which a vacuum was made in it, and dry carbonic acid gas was allowed to enter it alternately.

Experiments.—The receptacle to be filled is placed in broken melting ice, and a vacuum is maintained in it for at

* *Comptes Rendus*, January 17, 1898.

† *Comptes Rendus*, August 2, 1897.

least an hour, during which the dry gas enters it, bubble by bubble, passing over phosphoric anhydride. Communication between the receptacle and the atmosphere is then made for a few minutes, after which the receptacle is isolated, and, at the same instant, the atmospheric pressure is ascertained to the $\frac{1}{100}$ of a millimeter, by means of a good Regnault-Leduc barometer. Immediately afterwards, the other receptacle is proceeded with in the same manner; the two fillings being thus effected at intervals during a few hours, the pressures of the two gases are equal to within $\frac{1}{10}$ or $\frac{2}{10}$ of a millimeter, and as the volumes of the two receptacles are nearly equal, the mean of the two barometric heights observed (all corrections made) can be taken as the pressure of both fillings. The diffusion is allowed to proceed during several days, and is made more active by some variations of temperature; finally the pressure of the mixture is ascertained by connecting the receptacles with a Regnault manometer.

Care was taken to establish, *a priori*, a difference in the level of the mercury in the two branches of this manometer, corresponding to the difference between the barometric heights on the day of the filling and on the day of the measuring, and also corresponding to the variation of pressure produced by the mixing of the two gases, a variation approximately known by a preliminary experiment. In opening the cock of the two receptacles there was then observed only a very feeble movement of the mercury. The correction to be made to the pressure as read is very small, which is quite advantageous, as it is a little uncertain, because it requires a knowledge of the volumes of the communicating tubes.

RESULTS: 1ST, Az_2O AND CO_2.

Pressure of filling	759·40 millimeters.
Pressure of mixture	759·48 "

The very small augmentation of pressure (0·08 millimeter) can be attributed to experimental errors.

Note.—As the diffusing lasted only two days in this experiment, I assured myself by analyzing the gaseous mix-

ture in each of the two receptacles, that the mixing was nearly complete.

2D, SO_2 AND CO_2.

Pressure of CO_2 = 765·64 millimeters . . . . . } mean, 765·69
Pressure of SO_2 = 765·73 millimeters . . . . . }
After four days the pressure of the mixture was 766·90.
After seven days the pressure of the mixture was 767·05.

In this case there is distinctly observed an augmentation of pressure caused by the mixing, but its value (1·36 millimeters) is very inferior to what it should have been according to the old law of the mixture of gases. The difference in the results obtained in the two cases of the experiments can be attributed to the facts that CO_2 and Az_2O have the same molecular mass and are in corresponding states at 0° and under the atmospheric pressure, while such are not the same for CO_2 and SO_2.

To Résumé.—These results confirm those which have been obtained by the method of measuring by the densities;* and, like those, they show that the received law of gaseous mixtures should be abandoned where pressures intervene, and the law substituted which makes the volumes intervene.

THE WORK OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

An address by PROF. MANSFIELD MERRIMAN, of Lehigh University, Chairman of the American Section of the Association, at the second annual meeting, held in Pittsburgh, Pa., August 15-16, 1899.

Prior to the year 1800 little was known of the properties of the materials of construction. Galileo had shown, in 1638, that the strength of a rectangular beam varied with the square of its depth; Hooke, in 1678, had announced the law that the stretch of a spring was proportional to the stress upon it; various authors had discussed the forms of beams of uniform strength, and Euler, in 1744, had enunciated his formula for the resistance of columns under compression. Theory was far in advance of practice, for experiments had been so few and so imperfect that the elastic limit was scarcely recognized.

* Mr. Leduc has found, by the method of densities, that the mixing of SO_2 and CO_2 is accompanied by an augmentation of pressure of 1·25 millimeters, but the pressure of the mixture was only 66 millimeters instead of 77 millimeters.

During the years from 1800 to 1850 great progress was made in the theory of elasticity, and a slow growth took place in knowledge of the properties of materials under stress. The introduction of railroads and the consequent necessity of providing a firm roadbed and safe bridge structures gave a powerful stimulus to the investigation of metals in order that ample security might be afforded with the greatest degree of economy. The methods of testing were, however, so imperfect that progress was slow, and, with the exception of the classic researches of Hodgskinson, the work of this period was mostly of value as a preparation for that of the future.

After 1850 large testing machines for special purposes began to be built, elongation and ductility began to be carefully studied, and soon after 1870 it was recognized by many manufacturers that physical tests of metals were imperatively necessary in order to secure uniformity of product. As these tests were multiplied and the records subjected to investigation, the knowledge was gained that the strength of a specimen depended upon its size and proportions and also upon the manner in which the load was applied. The term elastic limit assumed a new significance when it became recognized that it could be defined and measured in different ways. In short, it was found that tests of materials must be made in a similar manner in order to render the results comparable. This idea, although long recognized, has proved a difficult one to realize. It has been discussed by many engineering societies, some of which have attempted to formulate methods. Finally, the International Association for Testing Materials was formed in order to study the whole subject and endeavor to arrive at conclusions that should be authoritative.

In 1882, through the influence of John Bauschinger, a number of German experimentors met at Munich and discussed the question as to how uniformity in the methods of testing materials could be promoted. As a result of this meeting, formal conferences were held at Dresden in 1884, at Berlin in 1886, at Munich in 1888 and at Vienna in 1893, delegates from other European countries being often present. The reports of the proceedings of these conferences attracted wide attention, and the great value and importance of the discussions became universally recognized in engineering circles. In short, the movement assumed an international character.

In 1890, as a result of the international congresses of engineering held at Paris in the preceding year, the French government appointed a commission to formulate standard methods for testing the materials of construction. Its report, published in 1894, in four large volumes, is one of the most valuable contributions to the subject, but from the first it was recognized that ultimate conclusions could not be determined by a commission of one nationality, and accordingly, since 1895, the French government has given hearty support to the work of the International Association.

In 1895, as a result of the four preceding conferences, the fifth conference met at Zurich, all European countries, except Turkey, being represented. The United States Government was represented by an army officer and the American Society of Mechanical Engineers by a delegate. At this congress the International Association for Testing Materials was formally organized, its object being, as stated in its statutes, "the development and unification of standard methods of testing for the determination of the properties of the

materials of construction and of other materials, and also the perfection of apparatus for that purpose." This meeting at Zurich hence assumed an importance far greater than any preceding conference, and it may be called the first congress of the International Association.

At the Vienna Convention of 1893 there had been appointed twenty committees on technical subjects, and reports from many of these were presented at the Zurich Congress of 1895. These reports were published in the French and German languages in the official organ of the Association, called *Baumaterialienkunde*, the first number of which appeared in July, 1896. The work of some of these committees was continued, other subjects were proposed for future consideration, and a council was organized to transact the business of the International Association in the intervals between the congresses.

In 1897 the second congress of the International Association was held at Stockholm, there being present 361 members, representing eighteen countries. The United States Government was represented by an army officer and a navy officer, and the American Society of Mechanical Engineers by a delegate. The congress continued in session for three days, reports of committees were presented, papers read and discussed, and plans outlined for the future work. It was resolved that the next congress should be held in Paris in the summer of 1900, and the council was authorized to appoint technical committees to make reports at that time on special problems relating to the objects of the Association.

At a meeting of the International Council held early in 1898 appointments were made of chairmen of nineteen committees on technical problems, and the number of members on each committee from each country was assigned. It was also recommended, in order to expedite the appointment and work of these committees, that the members in each country should meet and form a national section of the International Association. In compliance with this recommendation, a number of the American members met on June 15, 1898, and organized an American Section, whose first annual meeting was held at Philadelphia on August 27, 1898, and whose second annual meeting I now have the honor to address.

The membership of the International Association numbered 493 in 1895, 953 in 1896, 1,169 in 1897, 1,488 in 1898, and is now probably about 2,000. Germany takes the lead in regard to number of members, it having 387 in 1898, while Russia had 315, Austria 158, England 83, Switzerland 83, United States 68, Sweden 68, France 66, Holland 48, Norway 42, Denmark 39, Spain 36, Italy 35, and 60 from nine other countries. With regard to the American membership, it may be noted that it numbered 6 in 1895, 25 in 1896, 60 in 1897, 68 in 1898 prior to the organization of the American Section, 106 in February, 1899, and that it is now nearly or quite 125.

There are two peculiarities regarding membership in this Association that deserve notice. First, there is no nomination or election of members, but any person desiring to be a member may do so on signing a statement that he assumes membership and will be governed by the laws of the Association; in so doing he further assumes the obligation, stated in Article V of the statutes, that he will advance its interests to the best of his ability. Membership is hence a voluntary act assumed by an individual in order to promote the

knowledge of the properties of materials and to endeavor to secure uniformity in methods of testing them. Withdrawal from membership may be made at any time by mere announcement to the proper officer of the Association.

The second noteworthy feature regarding membership is that it may be assumed by a corporation or society as well as by a person. For example, in the list of members of the American Section, published in February last, will be found the Franklin Institute, the American Society of Mechanical Engineers, the American Foundrymen's Association and five local engineering clubs, as also several steel companies, engineering journals and firms engaged in inspecting and testing. In Europe this feature is carried much further, the membership of the German Section including the bureau of public works of several cities, provinces and States, the police bureau of Berlin, the Prussian War Department and the boards of direction of numerous railroads, as also a large number of manufacturing corporations and engineering societies. Under this arrangement it is possible for a corporation to exert a greater influence than through the indirect individual membership of its president or superintendent, both manufacturers and consumers can make their wishes more directly known, and thus differences in regard to methods of inspection and testing can be more quickly harmonized than under the usual plan of strict individual membership. However, fully three-fourths of the total members are individuals, and these include engineers in all branches, architects, chemists, professors of mechanics and engineering, and superintendents and foremen of works.

At the Zurich Congress the dues of members were fixed at $1 per year, and while no change was made at the Stockholm Congress, the Council recommended early in 1898, in view of the heavy expenses, that each member should pay $1.50 per year. Accordingly, at the first annual meeting of this Section, when our present by-laws were adopted, the provision was inserted that each member should pay $2.50 per year, of which $1.50 should be transmitted to the International Association and the remainder be used to defray the expenses of the American Section. This by-law went into effect on January 1, 1899, and accordingly no dues were collected by this Section for the year 1898, the $1.50 payable for that year being forwarded to the International Council directly by each member or through the American member of that Council. During the present year dues have been paid directly to our Secretary, and his report, together with that of our Treasurer, will be laid before this meeting.

The dues of $1.50 per year per member transmitted to the International Council are used by it in issuing its publications and in assisting its committees in defraying a part of the expenses of their special investigations. In addition to this income, a number of societies and bureaus have agreed to make extra annual contributions, the Prussian War Department heading the list with $125, and twenty-one others giving smaller sums, so that for the year 1898 the amount derived from these sources was about $400. Although official information is not at hand, it is safe to say that the total income of the International Association for the year 1898 did not exceed $2,000, which is certainly a small sum with which to issue its publications and carry on the work of twenty-one committees.

The International Association has issued yearly since 1895 a list of members, and also abstracts of the proceedings of the congresses of 1895 and 1897.

These, together with a few circulars of information, constitute all the publications that it has been able to furnish free to its members. The detailed proceedings of the congresses have been printed in the journal *Baumaterialienkunde*, published in the French and German languages, at Stuttgart, which has been furnished to members at $2.50 per year, the regular subscription price being $3.50. It will be seen, therefore, that an American member who desires to be fully informed regarding the work of the Association must necessarily subscribe to this journal, and by so doing his dues become really $5 per year. It should further be stated that arrangements will probably be made so that the official announcements of the International Council and the proceedings of future congresses will be printed in this journal in the English language, as well as in German and French.

The American Section, as already stated, had no income during 1898, and the report of our Treasurer shows that during the present year the amount available for expenses has been about $120. On February 18th a pamphlet of twenty-six pages was issued, containing a list of officers of the International Association and its committees and a list of the American members, together with the statutes, by-laws and some historical information. In April a bulletin was issued giving abstracts of the proceedings of the first annual meeting and of the meetings of the Executive Committee, and in July a second bulletin was issued containing the preliminary program for this meeting. It is hoped that the condition of our treasury may permit these bulletins to be continued, and that one may be issued containing the proceedings of this meeting.

The technical questions proposed for discussion at the Paris Congress of 1900 are nineteen in number. The organization of the international committees which are to consider these topics is now complete, and preliminary reports from the American members of several of them are to be presented and discussed at this meeting. Probably the most important of these subjects is that of standard international specifications for testing and inspecting iron and steel; this committee originally consisted of about forty members, of which five were assigned to this country, but under authority to increase its numbers the American sub-committee has been enlarged to twenty-one, has held several meetings, collected specifications and will present a preliminary report of much interest. It is also expected that the American members of five other international committees on iron and steel will report progress in their organization and work. As the national sub-committees are now in full correspondence with the international chairmen, it is expected that the final reports, which are to be presented for discussion at the Paris Congress, will prove of great interest and value.

Of the nineteen problems to be considered by the nineteen International Committees, six are on iron and steel; one on stone and slate; eight on cements and mortars; one on tile pipe; one on paints; one on lubricants, and one on the dry rot of wood. The fact that there are eight committees on cements and mortars and only six on iron and steel may seem abnormal, but it should be remembered that in the testing of hydraulic cement the personal equation of the observer enters to a far greater degree than in the case of metals, and that its rapidly increasing use demands the immediate perfection of methods which will render comparable the work of differ-

ent laboratories. At the session to-morrow morning preliminary reports from some of our sub-committees on these questions will be presented.

While the main object of the Association is to establish standard rules for testing, it is recognized that this cannot be done until a thorough knowledge is obtained of the properties of materials under varying conditions. Accordingly, the work of some of the committees is to collect and digest the information now on record, or to make scientific investigations that will render present knowledge more complete and definite. Thus, there is a committee on the properties of steel at abnormally low temperatures, one on the relation of the chemical composition of stone to its weathering qualities, one to digest the work of previous conferences and conventions on the adhesion of hydraulic cement, one on the causes of the abnormal behavior of cements as to time of setting, and one on the protection of wood against the action of dry rot. Some of these subjects have already been discussed at the congresses of Zurich and Stockholm, and accordingly the reports to be presented to the Paris Congress should contain positive additions to present knowledge.

At the annual meeting of this section, held last year, the desire was expressed to discuss the subject of impact tests, and a special committee was appointed whose report will be presented at this meeting. Later, other members requested that other problems should be taken up by the section, and accordingly three other American committees have been organized on special problems connected with the manufacture of iron and steel. While these committees have no connection with the international ones, it is believed that their work will add to the interest of our annual meetings, and further the general objects of the Association.

There are advantages and disadvantages in doing technical work by committees. One advantage accrues through the harmonization of the different views held by individuals, whereby non-essentials are rejected and only fundamental methods retained. One of the disadvantages is that this process of harmonizing views takes time, causing reports to be long delayed, particularly with international committees. Some technical societies appoint committees with great reluctance, fearing that their reports may be regarded as official action. In the case of our international organization, no such fear is felt, and the report of a committee is to be considered from the same point of view as the paper of an individual member. Through the formation of the national sections, the work of the international committees can certainly be made more valuable and effective than ever before, for each national sub-committee, after having eliminated disagreements of its individual members, can work as a body to impress its views upon the other national sub-committees. In many cases an international agreement may be found difficult to make, but if made after such full discussion it will be sure to be authoritative and valuable.

The subject of the chemical analysis of iron and steel has been discussed in previous conferences and congresses, and at the Stockholm meeting of 1897 it was formally resolved to establish an international sidero-chemical laboratory at Zurich. It was stated that fifteen smelting companies and iron manufacturers had pledged themselves to contribute $3,500 per year for this purpose, and that the Polytechnicum at Zurich had offered the use of four well-equipped rooms. It was, accordingly, determined to open the laboratory in

1898, and an international commission was appointed to take charge of it and raise further funds for its maintenance. I am unable to state how fully this has been carried out, as no published accounts of its work have appeared. It it, however, to be doubted whether the establishment of chemical and physical laboratories falls properly within the scope of the objects of the Association. If sufficient funds could be raised so that men of different nationalities might meet at such a laboratory to actually make analyses and tests, each criticising the others, while at the same time learning from them, then undoubtedly effective work would be done in harmonizing differences and perfecting standard methods. It is to be hoped, if the establishment of the sidero-chemical laboratory at Zurich proves to be successful, that it may tend to further this method of research. It is however, the opinion of many members that results as good, if not better, would be secured by arranging systematic schemes of investigation and distributing the actual work of analysis or testing among the laboratories of different countries.

A brief history of the organization and work of the International Association for Testing Materials, and of that of its American Section, has now been given. The great interest taken in the movement in so many countries is an index of the necessity felt in all branches of the engineering profession for the introduction of uniform methods of testing and inspecting the materials of construction. This work is one that must occupy many years, and which in a certain sense can never be finished, for constant progress will be made in our knowledge of the properties of materials. In order to carry it on with success it is apparent that more money will be needed than the small amount now raised from the annual dues of members. In Europe the importance of the work of the Association is forcibly attested by the fact that engineering societies, bureaus of public works, iron and cement manufacturers, and railroads assist it by extra annual contributions, and it is to be hoped that the influence of this Section may be sufficient to cause similar substantial gifts to flow into its treasury from American corporations A proposition to establish a fund for research and publication will be introduced for discussion at this meeting.

Since the above was written a circular of the International Council has been received, containing the information that probably arrangements cannot be made for holding the congress of the Association at Paris in 1900. It appears that the authorities of the Paris Exposition have the right to control the organization of all congresses held in that city in that year, and that they have announced one to be held on the subject of materials, and appointed officers to conduct the same. The subject will be discussed at this annual meeting, and expressions of opinion are desired as to whether it is best to abandon our congress of 1900, in order to co-operate with the one announced by the authorities of the Paris Exposition, or to hold it at London during the week preceding.

In conclusion, it is with pleasure that I congratulate the American Section upon its activity and the Association itself upon the bright prospects before it. The undertaking inaugurated by Bauschinger and his associates bore good fruit at the conventions of 1884, 1886, 1888 and 1893, and prepared the way for the Zurich meeting of 1895, which was at the same time the fifth convention and the first congress. At the Stockholm Congress of 1897 the true inter-

national work was begun, and the problems there proposed are now the subject of careful study in all parts of the earth. Let us hope that the reports to be presented at the future congresses will be such as to add to the present stock of knowledge, prove advantageous to both producers and consumers, and assist all engineers in economically using the materials and forces of nature for the benefit of man.

NOTES AND COMMENTS.

AMMONIA AS A FIRE-EXTINGUISHER.

The editor of the *National Druggist* gives some highly interesting information respecting the fire-extinguishing qualities of aqua ammoniæ, which are worthy of attention, as the following statements will indicate:

"In one instance, where fire had originated, probably from spontaneous combustion, in a pile containing several tons of cotton-seed, and the interior of which was almost a solid body of live coal, a half gallon of ammonia completely smothered the fire. In another, which occurred in Savenay, France, the vapors of a tank containing 50 gallons of gasoline caught fire in the linen room of a laundry. The room was instantly a mass of living flames, but a gallon and a half of ammonia water thrown into it completely and almost immediately extinguished the fire. The ammonia was in a glass demijohn in an apothecary's shop next door to the laundry, and was thrown into the room by the druggist as an experiment. To use his own words in reporting the circumstance * * * 'The effect was instantaneous, torrents of black smoke rolled upward in place of flames, and in a moment every trace of fire was gone. So completely was the fire extinguished, that workmen were enabled to enter the room almost immediately, where they found the iron tank of gasoline intact.' "

A SIMPLE SUGGESTION FOR REMOVING BOILER SCALE.

The following simple suggestion for the removal of scale from boilers is recorded in the Bulletin of the Society for the Encouragement of National Industry, in Paris. To this the interesting observation is reported that boiler scale is rendered quite loose, and is for the most part washed away on emptying out the water, if the boiler is allowed to cool off very slowly after being taken out of use. This graded cooling occupies considerable time—more or less, according to the size of the boiler; generally, however, from eight to ten days. The scale state remaining adherent to the shell, it is added, can be washed away by a strong jet of water.

It will occur at once to the mechanical reader that, however effective the process may be, it will scarcely come into general favor for the reason that it necessitates putting the boiler out of service for too long a time; but in cases where this circumstance happens to be not objectionable, it might be worthy of a trial. It is added, in relation to the subject, that this method will be found specially convenient for boilers with narrow pipes or parts that are difficult of access.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 20, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 82 members and visitors.

Additions to membership since last report, 71.

The Actuary reported that the Managers of the National Export Exposition have requested the Franklin Institute to undertake the duty of making the awards at the Exposition, under the rules of the Institute, and that the Board has accepted the responsibility.

The Secretary read the following extract from the minutes of the stated meeting of the Library Committee, held September 11, 1899, viz.:

"The Committee directed an entry to be made upon its minutes expressing the profound regret of the members at the death of William P. Tatham, for many years identified with the Committee as a member and as Chairman, and whose activity and zeal in furthering the interests of the Library are held in grateful remembrance."

The following amendments to the by-laws of the Institute were offered, and, in accordance with the usual course of procedure, were ordered to publication, viz.:

Resolved, That paragraph 1 of Section 8 of Article III be amended by striking out the word "fifty" and inserting in place thereof the words "twenty-five," so that the paragraph, as amended, shall read:

"Non-resident members shall be those who reside permanently at a distance not less than twenty-five miles from Philadelphia."

Resolved, That Section 2 of Article IV be amended by adding thereto the words:

"A non-resident life membership (not transferable) may be acquired by the payment of $40.00 in any one year," so that the section, as amended, shall read:

"Holders of second-class stock, and contributing members enrolled as non-resident members, shall pay, upon election to membership, an entrance fee of $5.00 and an annual fee of $2.00. A non-resident life membership (not transferable) may be acquired by the payment of $40.00 in any one year."

The President gave a brief account of the co-operative work of the Institute in connection with the National Export Exposition, and called upon Mr. Henry Howson, Chairman of the Committee on Exhibitions, for the details. Mr. Howson made a report, of which an abstract is given below, viz.:

ABSTRACT OF REPORT OF THE COMMITTEE ON EXHIBITIONS.

Your Committee presents the following report of its work and of those associated with it, in preparing for the National Export Exposition of 1899.

The Executive Committee of the National Export Exposition consists of representatives of the Exposition Association, an organization duly chartered to carry on an exposition, the Commercial Museums and the Franklin Institute. This Executive Committee was divided into numerous sub-committees, who were to do the actual work of preparing for the Exposition. These sub-committees are as follows:

Grounds and Buildings; Rules and Regulations; Amusements, Attractions and Concessions; Law; Publicity; Finance, Admittance and Insurance; Classification and Space. * * * *

Owing to the fact that the majority of the members of the Executive Committee were active business men, it was deemed advisable to have as few meetings as possible for the proper conduct of the work. The detail work was done by the several sub-committees above noted.

The reports of the sub-committees were made direct to the Board of Directors of the Exposition as the responsible head.

In all organizations of this kind some few members do the actual work, and the members representing the Franklin Institute have attended faithfully the meetings of the several sub-committees; in fact, we have always had a fair representation and oftentimes a majority of the members present, and the Board of Directors has invariably approved the work. We are happy to say the Exposition opened, on the 14th of September, under the most favorable conditions.

When we take into consideration the fact that in the spring of this year the contract for the buildings was not let, arrangements for space were not made, even the plans for the buildings were not drawn, and some of the ground not yet acquired, it was remarkable that the buildings were finished for the reception of goods before the opening day of the Exposition, and that the grounds were so near completion on the opening day; all this work being done under the most unfavorable circumstances, owing to the fact that the prices of materials were increasing by daily jumps, so that in making contracts we would have to make them immediately, otherwise we could not hold the contractors. In some cases iron was not available and wood had to be substituted, and when we substituted wood in the construction of the buildings, this was almost impossible to obtain without considerable delay; and yet, with all these difficulties in the way, the buildings were constructed on time, and if it had not been for the usual tardiness of exhibitors, the Exposition would have been much further advanced on the opening day than any important exposition held since the Centennial. * * * *

The buildings are three in number. The main building is about 1,000 feet long by 400 feet wide, and has a total area of 200,000 square feet. It is constructed of three permanent pavilions, which will eventually form the wings of the permanent buildings of the Commercial Museums, the south and central wings being connected by the main exhibition hall, which contains some of the finest exhibits that have ever been shown at an exposition. The three permanent pavilions and this exhibition hall were constructed by Mr. Rorke, and they were completed in time according to contract. The central pavilion is connected to the north pavilion by the auditorium, which is capable of seating 6,000 people, and on each side of the auditorium are wide exposition halls. This auditorium building was constructed by Mr. Seeds, and was com-

pleted about two weeks ahead of time, and this is certainly remarkable when we consider the times and the conditions under which the contractor had to work.

The Vehicle and Implement Building is 450 feet long and 160 feet wide, and the Transportation Building is 450 feet long by 75 feet wide. These two buildings were constructed by Messrs. Pennock Brothers, and they completed their work on time.

The exhibition space includes the entire lower floor of the main building, with the exception of the auditorium, the entire floor of the Vehicle and Implement Building and the entire Transportation Building.

The second floor of the central pavilion is devoted to an exhibit by the Commercial Museums, of goods manufactured in other countries for the export trade, while the second floor of the south wing is devoted to the executive offices of the Exposition Association, and the second floor of the north wing to the Convention Hall, a first-class restaurant, the Franklin Institute reception rooms and sundry committee rooms. * * * *

THE SEVENTY-FIFTH ANNIVERSARY.

In reference to the seventy-fifth anniversary, elaborate preparations have been made to celebrate the occasion during the first week of October, and it is hoped that the members of the Institute will aid the Committee by their support and attendance.

A program has been arranged giving each Section of the Institute one evening, and there will be a general Institute meeting on the closing night, Saturday, October 7th, at which Professor Thurston and Rear-Admiral Melville, Engineer-in-Chief of the U. S. Navy, will make the addresses.

Invitations are now being engraved and programs printed. These invitations and programs, together with the passes, will be received by each member within a week.

A Franklin Institute reception room has been provided on the second floor of the north pavilion of the Exposition Building, directly over the main entrance. An employé will be in attendance at this reception room during the Exposition, and it will be used as a reading and waiting room for the members and their friends. We hope that the members will avail themselves of this room.

The details, in reference to the awards, have not yet been worked out, but this matter has been placed entirely in the hands of the Franklin Institute.

* * * *

HENRY HOWSON,
Chairman Committee on Exhibitions.

PHILADELPHIA, September 20, 1899.

The Secretary called attention to the notable circumstance that the Honorable Frederick Fraley, one of Philadelphia's oldest and most distinguished citizens, was the sole survivor of the founders of the Institute, and urged the propriety of taking special action in connection therewith; whereupon the following resolution was adopted unanimously:

"The members of the Franklin Institute, in stated meeting assembled, and engaged in the consideration of plans for the celebration of the Seventy-fifth

Anniversary of the Society, by unanimous vote have instructed their President and Secretary, in their behalf, to convey to the Honorable Frederick Fraley, their cordial felicitations upon the unique circumstance that he, of all his colleagues, who attended the historic meeting in the County Court House, Sixth and Chestnut Streets, on February 5, 1824, to inaugurate the Franklin Institute, still survives, and to express their earnest hope and expectation that he will be able to honor the occasion of the closing ceremonies on 'Institute Day,' Saturday, October 7th, or any of the ceremonies of Institute week, in the Convention Hall of the National Export Exposition, with his presence and participation."

Mr. Joseph N. Goldbacher, of New York, gave a description of the Bournonville Acetylene Gas Machine, and exhibited the apparatus in operation.

Mr. James Hough, of New York, gave a description and exhibited the operation of a series of improved draughtsman's tables.

Adjourned.

WM. H. WAHL, *Secretary.*

PROVISIONAL PROGRAM OF THE SEVENTY-FIFTH ANNIVERSARY OF THE FRANKLIN INSTITUTE.

The celebration of the Seventy-fifth Anniversary of the Institute should properly have taken place on February 5, 1899. In view, however, of the circumstance that the Institute would probably participate in conducting the National Export Exposition in the autumn, it was decided by the Board of Managers to postpone the event and arrange to have the celebration take place during the exhibition, as part of the numerous public functions to be held in connection therewith.

In accordance with this decision, it has been arranged to hold in the Convention Hall of the Exposition, during the week beginning Monday, October 2d, and ending Saturday, October 7th, a series of special anniversary meetings under the direction of the several Sections of the Institute, to follow one another on successive evenings, and to be concluded by a special meeting of the Institute. At these meetings it has been arranged that addresses appropriate to the occasion shall be delivered by distinguished invited guests and members of the Institute. The series of meetings and addresses thus far tentatively arranged is as follows (*subject to change*):

MONDAY, OCTOBER 2D, 8 P.M. CHEMICAL SECTION.

Dr. Joseph W. Richards, Bethlehem, Pa., President of the Section. "Introductory Address."

Prof. Harvey W. Wiley, Washington, D. C. "The Progress of Chemistry as Applied to the Arts."

Dr. Charles F. Himes, Carlisle, Pa. "Photography and Microscopy in their Applications to the Arts" (Photographic and Microscopic Branch).

TUESDAY, OCTOBER 3D, 8 P.M. ELECTRICAL SECTION.

Dr. Edwin J. Houston, Philadelphia, Pa. "The Seventy-fifth Anniversary of the Franklin Institute from an Electrical Standpoint."

Mr. Ralph W. Pope, New York. "The Influence of such Societies as the Franklin Institute and the American Institute of Electrical Engineers in Promoting the Progress of the Electrical Arts."

Prof. F. B. Crocker, New York. "The Commercial Aspects of American Electrical Industries."

WEDNESDAY, OCTOBER 4TH, 8 P.M. MINING AND METALLURGICAL SECTION.

Mr. James Christie, Philadelphia, Pa., President of the Section. "Introductory Address."

Mr. Chas. Kirchhoff, New York. "Three-quarters of a Century's Progress in Mining and Metallurgy."

Mr. John Fritz, Bethlehem, Pa. "The Development of Iron Manufacture in the Past Seventy-five Years."

THURSDAY, OCTOBER 5TH, 8 P.M. MECHANICAL AND ENGINEERING SECTION.

Mr. Wilfred Lewis, Philadelphia, Pa., President of the Section. "Introductory Address."

Dr. Coleman Sellers, Philadelphia, Pa. "The Progress of the Mechanical Arts in Three-quarters of a Century."

FRIDAY, OCTOBER 6TH, 8 P.M. PHYSICAL AND ASTRONOMICAL SECTION.

Dr. A. E. Kennelly, Philadelphia, Pa., President of the Section. "Introductory Address."

Dr. T. C. Mendenhall, Worcester, Mass. "The Progress of Physics and Astronomy."

SATURDAY, OCTOBER 7TH, 8 P.M. "INSTITUTE DAY."

Mr. John Birkinbine, Philadelphia, Pa., President of the Institute. "Introductory Address."

Dr. Robert H. Thurston, Ithaca, N. Y. "The Evolution of Technical Education and its Progress during the Past Seventy-five Years."

Rear-Admiral Geo. W. Melville, Engineer-in-Chief, U. S. N. "The Modern Warship as Combining in Itself the Highest Results of Skill, Ingenuity and Scientific Knowledge."

[The presence and participation, on this occasion, of Hon. Frederick Fraley, the sole surviving foundation member of the Institute, are earnestly hoped for.]

The management of the National Export Exposition has extended to the members of the Institute and its invited guests the privilege of free admission during "Institute Week" (October 2d to October 7th, inclusive), and passes will be mailed to members in good standing prior to October 1st.